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THE LOESS SOILS OF THE NEBRASKA PORTION OF THE TRANSITION REGION:

IV. MECHANICAL COMPOSITION AND INORGANIC CONSTITUENTS[1]

BY

FREDERICK J. ALWAY, *Chief, Division of Soils,* AND CLAYTON O. ROST, *Research Assistant in Soils, Agricultural Experiment Station, University of Minnesota.*[2]

INTRODUCTION

In Nebraska the loess extends westward for about 300 miles from the eastern boundary on the Missouri River. Throughout this distance the temperature conditions are quite uniform, but there is a gradual decrease in the humidity of the climate, the normal annual precipitation, which exceeds 30 inches at the eastern boundary, steadily falling until it is less than 20 in the extreme western portion, while the rate of evaporation increases considerably. The climate of this region has been considered in detail in a previous paper (2, p. 206).

The soil samples, upon which this article is based, were collected from 30 virgin prairie fields, 5 near each of six stations of the United States Weather Bureau shown in figure 1—Wauneta, McCook, Holdrege, Hastings, Lincoln, and Weeping Water. In each field, at intervals of 30 feet, 10 borings were made to a depth of 6 feet and composite samples prepared of each foot-section, thus giving 6 samples from each field, the so-called "field-samples." From these "area-samples" were prepared for analysis by mixing equal weights of the corresponding five field samples. Thus each of the samples analyzed is a composite from 50 individual borings. The details of the method of sampling are given in the article referred to above.

[1] Received for publication February 10, 1916.

[2] The work reported in this paper was carried out at the Nebraska Agricultural Experiment Station, where the authors were Chemist and Assistant in Chemistry, respectively.

Mechanical Analysis.

Mechanical analyses of the area samples were made by the methods of the Bureau of Soils (4, 8). Deflocculation was effected by 7 hours' shaking of 5 gm. of soil with 75 c.c. of water to which there had been added 2 c.c. of ammonia solution. The clay was determined by difference. The organic matter was allowed to remain in the separates, being distributed among the different fractions. Only in the case of the coarse sand was it determined by ignition. This fraction from the surface foot samples showed root fragments, but in no sample did the organic matter in this exceed 0.2 per cent of the weight of the soil. As all the soils consisted chiefly of silt and very fine sand, the two fractions most difficult to separate satisfactorily, especially as so much of the very fine sand was but little coarser than silt, we were very careful to make the separations as

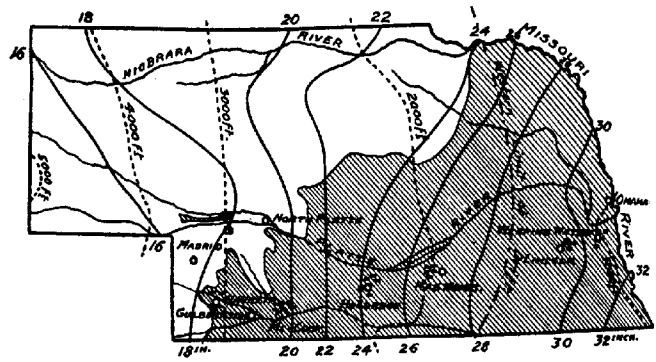

Fig. 1—Map of Nebraska showing distribution of the loess (shaded), annual precipitation and location of the fields sampled.

nearly alike as possible, all being carried out side by side. As a final precaution we compared under the microscope the corresponding fractions from the different samples, both before and after being dried.

The mechanical composition is shown in Table I and figure 2. All the samples consist chiefly of silt and very fine sand, the sum of these in no case being less than 77 or more than 95 per cent, it being highest in the most westerly three areas where it varies between 83.5 and 94.7 per cent. In the most easterly two it lies between the somewhat lower limits of 77.3 and 82.6 per cent, the decrease being compensated for by a corresponding increase in the amount of clay, which reaches a maximum of nearly 20 per cent in the eastern areas. The four fractions coarser than very fine sand together form only from 0.4 to 4.9 per cent, the fine sand constitu-

TABLE I

MECHANICAL ANALYSIS OF FOOT-SAMPLES FROM THE DIFFERENT AREAS

Depth Foot	Fine Gravel 2.0-1.0 mm. %	Coarse Sand 1.0-0.5 mm. %	Medium Sand 0.5-0.25 mm. %	Fine Sand 0.25-0.10 mm. %	Very Fine Sand 0.10-0.05 mm. %	Silt 0.5-0.005 mm. %	Clay 0.005-0.000 mm. %
WAUNETA							
1	0.0	0.1	1.0	3.7	48.7	41.2	5.4
2	0.0	0.1	0.5	1.8	47.8	43.3	6.6
3	0.0	0.1	0.3	1.6	46.8	43.8	7.5
4	0.0	0.1	0.0	1.6	47.6	41.3	9.5
5	0.0	0.0	0.1	1.4	50.0	43.6	4.9
6	0.0	0.1	0.1	1.1	54.9	39.8	4.2
Average	0.0	0.1	0.3	1.9	49.3	42.2	6.3
McCOOK							
1	0.0	0.3	0.8	2.6	39.0	48.6	8.7
2	0.0	0.0	1.1	1.5	37.8	50.1	9.5
3	0.0	0.1	0.1	1.1	36.4	53.9	8.4
4	0.0	0.1	0.1	1.2	38.9	52.4	7.4
5	0.0	0.1	0.1	1.6	39.3	52.6	6.3
6	0.0	0.1	0.1	1.0	40.4	51.8	6.6
Average	0.0	0.1	0.4	1.5	38.6	51.6	7.8
HOLDREGE							
1	0.0	0.3	0.4	2.1	25.9	64.6	6.7
2	0.0	0.1	0.3	0.9	24.6	62.9	11.2
3	0.0	0.1	0.1	0.6	26.2	62.5	10.5
4	0.0	0.2	0.1	0.6	27.8	64.8	6.4
5	0.0	0.2	0.4	1.9	31.7	60.0	5.8
6	0.0	0.2	0.4	1.8	31.1	60.7	5.8
Average	0.0	0.2	0.3	1.3	27.9	62.6	7.7
HASTINGS							
1	0.0	0.3	0.7	2.9	23.9	64.6	7.6
2	0.0	0.0	0.5	2.2	20.3	64.5	12.5
3	0.0	0.0	0.6	1.7	22.2	61.9	13.6
4	0.0	0.2	0.4	1.5	21.5	62.4	14.0
5	0.0	0.2	0.5	1.7	20.9	66.7	10.0
6	0.0	0.3	0.4	1.5	20.7	67.2	9.9
Average	0.0	0.2	0.5	1.9	21.6	64.5	11.3
LINCOLN							
1	0.0	0.3	0.6	2.9	13.5	68.0	14.8
2	0.0	0.3	0.7	2.7	9.8	67.6	18.9
3	0.0	0.4	0.7	2.3	9.3	68.0	19.3
4	0.0	0.4	0.7	2.1	9.6	68.1	18.9
5	0.0	0.8	0.8	2.1	9.9	69.4	17.0
6	0.2	0.5	0.9	2.3	9.5	70.2	16.5
Average	0.1	0.4	0.7	2.4	10.3	68.5	17.6
WEEPING WATER							
1	0.0	0.5	0.7	3.0	9.7	72.2	13.9
2	0.0	0.1	0.5	2.2	8.2	69.5	19.6
3	0.0	0.1	0.1	0.8	13.8	66.7	18.6
4	0.0	0.1	0.1	0.4	14.9	67.0	17.6
5	0.0	0.1	0.1	0.3	14.7	67.9	17.0
6	0.0	0.1	0.1	0.3	15.0	67.5	17.1
Average	0.0	0.2	0.3	1.2	12.7	68.5	17.3
Av. of all Samples	0.0	0.2	0.4	1.7	26.7	59.7	11.3

ting the most of this. In only the sixth foot of the Lincoln area were any particles coarser than 1.0 mm. found. These came from Field III in which the loess was thinest, and appear to have been derived from a boring that had barely penetrated the underlying Kansan till.

It will be seen that the amounts of the chief constituents, silt and very fine sand, show no distinct dependence upon the depth. In all the areas the proportion of clay is lower in the first than in the second foot, and shows a maximum in the second, third or fourth foot. The fine sand, low at all depths, is, in general, present in largest amount in the first foot.

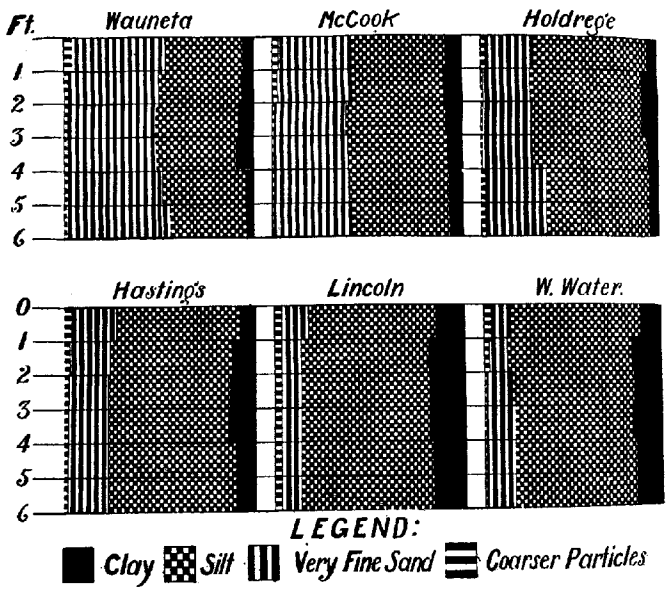

Fig. 2—Diagram showing the mechanical composition of the composite samples from the different areas.

As we pass from west to east the texture of the loess becomes finer. The proportions of the fractions coarser than 0.1 mm. are quite similar in all the areas, but those of both clay and silt are highest, and those of very fine sand lowest, in the eastern areas. However, when we compare the samples from two adjacent areas we do not find a regular increase or decrease in the amount of the different separates on passing from west to east. The Wauneta and McCook samples are quite similar, as are also those from Lincoln and Weeping Water, while the soils from the two intervening areas are intermediate in texture. The very fine sand shows

a steady decrease from Wauneta to Lincoln and then rises somewhat in the Weeping Water area. The silt rises from Wauneta to Holdrege and Hastings and again at Lincoln and Weeping Water. The clay is similar in amount at Wauneta and McCook, being low at both, is higher in the second and third foot at Holdrege, still higher at Hastings and much higher at both Lincoln and Weeping Water.

The Bureau of Soils of the United States Department of Agriculture[1] has reported the mechanical analyses of 20 samples of loess soils from Nebraska. None of these was taken from any point farther west than Holdrege. Half of them were surface soils taken to a depth of 12 to 16 inches, while the others were the corresponding subsoils, taken to represent the section between the surface sample and a depth of 36 inches. The analyses of these, only a few of which were composites, are on the whole quite concordant with those reported in Table I, if we omit from the comparison the data from the Wauneta area.

At the time our samples were collected only the fields near Lincoln had been included in a soil survey. Since then those of the westerly four areas have been covered by a reconnoissance survey of Western Nebraska (7) and those near Weeping Water by a detailed survey.[2] All the fields at Wauneta, McCook, Holdrege and Hastings from which the samples were taken are indicated on the map of the reconnoissance survey as Colby silt loam—"An ashy-gray to brownish-gray silt loam with a small content of fine sand and clay, ranging in depth from 6 to 24 inches. . . . . The type is of wind-laid origin and is derived from the weathering of loess" (15, p. 427).

The fields at Lincoln were selected from the areas indicated on the soil map of Lancaster County as Marshall silt loam. Of the five fields at Weeping Water the Bureau of Soils, on the map in its recent report, indicates two, IV and V, as Marshall silt loam, but the other three as Shelby silt loam. The former is described as "a dark brown to black silt loam, 15 inches deep, resting usually upon a light-colored, sometimes mottled, silt loam or silty clay. . . . . The soil is derived from loessial deposits" (15, p. 158). The latter is "a dark-brown or dark grayish brown, heavy silt loam 8 to 15 inches deep, underlain by a light-brown or yellowish brown, compact silty clay. . . . . The nearness of the Kansan drift to the surface varies with the topographic position of this soil. . . . . The divides are covered with a thick mantle of silt. The Shelby and Marshall silt loams are very similar in this county and differ mainly in point of origin. The Shelby silt loam is derived from the weathered phase of the

[1] Soil Survey of the Stanton Area, 1904, Grand Island Area, 1904, Kearney Area, 1904, Sarpy Area, 1906, Lancaster Area, 1908.

[2] Soil Survey of Cass County, Nebraska, Bureau of Soils, U. S. D. A., 1914.

Kansan drift, whereas the Marshall silt loam is derived from loess. The latter carries no pebbles or boulders; the former a little of such coarse materials. . . . . These two types grade imperceptibly into each other, and the boundary between them is nessarily largely arbitrary."[1] In the latter report it is stated (p. 28) that "the Shelby silt loam also includes small areas of Marshall silt loam, which, owing to their close similarity to the former cannot be satisfactorily separated."

In order to decide whether we were in error in selecting the fields as all typical of the loess we have determined the amount of coarse and medium sands in each foot-sample from the three of our fields indicated on the Bureau of Soils Map as Shelby silt loam, and find the amount no higher than in the other two (Table II). This together with the fact that no gravel was found in any may be considered as conclusive evidence that no glacial drift was included in any of the samples, and that the soil of these fields has been derived from the loess and not from Kansan till.

TABLE II

COARSE AND MEDIUM SAND IN FIELDS AT WEEPING WATER

Depth	Field I	Field II	Field III	Fields IV & V
Foot	%	%	%	%
1	.3	.7	.5	1.1
2	.4	.5	.5	.8
3	.4	.6	.1	.1
4	.3	.3	.2	.1
5	.1	.1	.1	.1
6	.1	.1	.2	.1

Relation of Hygroscopicity to Mechanical Composition

The hygroscopic coefficients of the area samples have been previously reported (2, p. 216). Using the formula proposed by Briggs and Schantz (6, p. 73)—Hygroscopic coefficient = 0.007 sands + 0.082 silt + 0.39 clay—we have calculated the values from the data in Table I. These as well as the coefficients obtained by direct determination are reported in Table III. In the case of the Weeping Water and Lincoln samples the values obtained by the two methods agree satisfactorily, but a gradually increasing divergence is to be observed as we proceed westward from Lincoln. This corresponds to the increasing proportion of very fine sand and we find that by replacing the value 0.007, which Briggs and Shantz assign to all the sands, by 0.07 for very fine sand and by 0.005 for the coarser fractions we obtain a formula which applies equally well to the samples from all the areas. Hygroscopic coefficient = 0.005 coarser fractions + 0.07 very fine sand + 0.082 silt + 0.39 clay. In this modified formula the very fine sand is given a value almost as high as the silt. The material in the loess which falls into the former fraction consists chiefly of particles

[1] Soil Survey of Cass County, Nebraska, p. 27 to 29.

with a diameter but little in excess of 0.05 mm. and which, accordingly, differ but slightly from the silt particles. The effect both of the fine sand and of the coarser fractions might be ignored in such a calculation without the results being appreciably affected. We have found that dune sand, consisting of about 97 per cent of these fractions, has a hygroscopic coefficient of 0.4 or 0.5. For this reason in the proposed formula we assign the value 0.005 to the fractions coarser than 0.10 mm.

TABLE III

COMPARISON OF THE DETERMINED HYGROSCOPIC COEFFICIENTS WITH THE VALUES FOUND BY COMPUTATION FROM THE MECHANICAL ANALYSES: A. BY FORMULA OF BRIGGS AND SHANTZ; B. BY A MODIFIED FORMULA

	WAUNETA			McCOOK			HOLDREGE		
Depth Foot	Det'd	Computed		Det'd	Computed		Det'd	Computed	
		A %	B %	%	A %	B %	%	A %	B %
1	9.1	5.8	8.9	10.0	7.5	10.1	10.1	8.1	9.7
2	9.6	6.5	9.5	10.9	8.1	10.5	11.2	9.7	11.2
3	9.7	6.8	9.8	10.7	8.0	10.3	11.3	9.4	11.1
4	9.9	7.4	10.4	9.7	7.4	9.9	10.2	8.0	9.8
5	9.0	5.8	9.0	9.1	7.1	9.5	9.6	7.4	9.4
6	8.3	5.2	8.7	9.1	7.0	9.6	9.4	7.4	9.4
Av.	9.3	6.3	9.4	9.9	7.5	10.0	10.3	8.3	10.1
	HASTINGS			LINCOLN			WEEPING WATER		
1	9.6	8.5	9.9	12.0	11.5	12.3	12.1	11.4	12.0
2	11.6	10.3	11.6	14.4	13.0	13.6	13.7	13.4	13.9
3	12.4	10.6	11.9	13.6	13.1	13.7	13.9	12.8	13.7
4	11.1	10.7	12.1	13.0	13.0	13.6	13.0	12.5	13.4
5	10.7	9.5	10.8	12.8	12.4	13.0	12.6	12.3	13.2
6	10.7	9.4	10.8	12.7	12.2	12.9	12.5	12.3	13.2
Av.	11.0	9.8	11.2	13.1	12.5	13.2	13.0	12.4	13.2

As an illustration of the significance in field studies of soil moisture of the difference between the actual hygroscopic coefficients and those computed by the Briggs and Shantz formula, assuming an average difference of 3.0, as found with the Wauneta samples, we may cite the instance of a neglected old orchard near McCook which was, during a very dry period in 1912, succumbing to drought. In the first six feet there was an average of only 1.1 per cent of free water (Table IV), while the calculated values of the hygroscropic coefficients would have indicated 4.1 per cent. However, under favorable moisture conditions, the same soil would carry from 8 to 15 per cent free water, and then the difference between the actual amount and that calculated by the Briggs-Shantz formula would have little significance.

Methods of Chemical Analysis

All of the area-samples were subjected to a complete or rock analysis and also to extraction with strong hydrochloric acid. In the case of the "field samples" determinations of only the carbon dioxide were made.

In the complete analyses we followed the methods in use in the laboratory of the United States Geological Survey (13), except in the case of manganese. In determining this element by the method used in that laboratory we obtained discordant results. A new method was then developed (9) which we have used with all the samples.

TABLE IV

MOISTURE CONDITIONS IN AN OLD ORCHARD NEAR McCOOK, NEBRASKA, ON JUNE 27, 1912. AT THE TIME OF SAMPLING THE TREES WERE SUCCUMBING TO DROUGHT

Depth Foot	Total Water	Hygroscopic Coefficient		Free Water	
		A Determined	B Calculated	By A	By B
	%	%	%	%	%
1	10.2	8.4	5.4	1.8	4.8
2	13.0	10.6	7.6	2.4	5.4
3	10.7	9.8	6.8	0.9	3.9
4	9.5	8.9	5.9	0.6	3.6
5	9.3	8.9	5.9	0.4	3.4
6	8.9	8.3	5.3	0.6	3.6
Average	10.3	9.1	6.1	1.1	4.1

The determination of the acid-soluble constituents—the so-called zeolithic portion—was made by what is essentially Hilgard's method (11, p. 16). The soil was digested for 120 hours on the steam bath with hydrochloric acid of 1.115 specific gravity, after which the acid extract was analyzed by the methods recommended by the Association of Official Agricultural Chemists (3, p. 15) except that manganese was determined by the Gortner-Rost method mentioned above.

All analytical data reported are the averages of concordant duplicate determinations, except in the case of the silica, alumina, magnesia, lime and titanium oxide of the rock analyses. In the case of such complete analyses a partial control is provided by the magnitude of the departure of the sum of the constituents from 100 per cent.

The distribution of the different inorganic constituents is reported in Tables V to XVIII. The first part of each table shows the total amount of the constituent, the second, where given, the amount dissolved by 5 days' digestion with strong hydrochloric acid, and the third the portion remaining undissolved. The data in the last are not the result of direct determinations, they being obtained by subtracting the values in the second part from those in the first. Baryta was not found in the acid ex-

tracts and hence only the total is reported. The sum of the constituents remaining undissolved should approximate, but not necessarily be indentical with, the amount of insoluble matter found by digestion, as the difference between the two represents the summation of departures for the eleven soluble constituents.

LIME

The lime (Table V) shows greater variations than any other constituent, except the carbon dioxide. The total amount rises from east to west, being three times as high in the lower levels of the most westerly two areas as in those of the most easterly two. In the former it is much lower in the first and second foot than in the underlying levels, but in the

TABLE V
LIME IN THE FOOT-SECTIONS

TOTAL

Depth Foot	Wauneta %	McCook %	Holdrege %	Hastings %	Lincoln %	W. Water %	Average %
1	1.67	1.40	1.18	1.13	.72	.89	1.16
2	1.69	1.80	1.33	1.16	1.00	.95	1.32
3	2.72	3.59	1.60	1.45	1.21	1.37	1.99
4	3.93	3.91	2.15	1.75	1.21	1.08	2.34
5	3.91	3.54	2.30	1.80	1.39	1.08	2.34
6	3.94	3.44	2.19	1.72	1.31	1.18	2.30
Average	2.98	2.95	1.79	1.50	1.14	1.09	1.91

ACID-SOLUBLE

1	1.10	.88	.74	.68	.61	.68	.78
2	1.15	1.38	.86	.74	.64	.71	.91
3	1.81	3.03	.97	.97	.75	.76	1.38
4	3.06	3.33	1.69	1.22	.90	.78	1.83
5	3.04	3.04	1.84	1.33	1.10	.78	1.85
6	3.43	2.84	1.84	1.36	.96	.99	1.90
Average	2.26	2.42	1.32	1.05	.83	.78	1.44

ACID-INSOLUBLE

1	.57	.52	.44	.45	.11	.21	.38
2	.54	.42	.47	.42	.36	.24	.41
3	.91	.56	.63	.48	.46	.61	.61
4	.87	.58	.46	.53	.31	.30	.51
5	.87	.50	.46	.47	.29	.30	.48
6	.51	.60	.35	.36	.35	.19	.39
Average	.72	.53	.47	.45	.31	.31	.46

latter it shows no direct dependence upon the depth. The Holdrege and Hastings soils in this, as in almost every other respect, show a behavior intermediate between that of the two areas to the west and that of the two to the east. This marked variation is due chiefly to the acid-soluble portion. The insoluble part shows no distinct relation to the depth, but rises somewhat from east to west.

Carbon Dioxide

The variation in the carbon dioxide (Table VI) agrees with that of the acid-soluble lime, varying from an amount too small to be determined by ordinary methods to 2.34 per cent. Carbonates are practically absent from the first foot of all the fields, and from the second foot also, except in the case of three fields at McCook, the amounts found being within the range of experimental error.

TABLE VI

CARBON DIOXIDE IN THE FOOT-SECTIONS.

Depth Foot	Wauneta %	McCook %	Holdrege %	Hastings %	Lincoln %	W. Water %	Average %
1	.09	.02	.01	.01	.01	.01	.02
2	.07	.40	.03	.02	.02	.01	.09
3	.59	2.02	.13	.10	.02	.05	.48
4	1.67	2.34	.75	.36	.06	.00	.87
5	1.78	2.11	1.00	.38	.12	.02	.90
6	1.68	2.08	1.05	.41	.08	.01	.88
Average	.98	1.49	.49	.21	.05	.02	.54

The subsoils of the Weeping Water area show no carbonates. At Lincoln an appreciable amount is found only in the lower levels, where it occurs in the form of small concretions of calcium carbonate distributed through the fourth, the fifth and the sixth foot. In the lower levels at Hastings it occurs in considerable quantities, at Holdrege in large amounts and in the McCook and Wauneta fields it is still more abundant. In the western areas the carbonates are distributed throughout the subsoil mass instead of being segregated in the form of concretions. As it is important to know whether these differences in the amount of carbonates in the lower levels are common to all the fields of the areas concerned, we determined the carbon dioxide in the case of all the fields at Wauneta, McCook and Holdrege, except where the analysis of the composite had shown a negligible amount (Table VII). All the fields of these three areas show a high content of carbonates (0.33 to 3.05 per cent CO_2) in the fourth, the fifth and the sixth foot. The amount in the third foot is much more variable, while that in the first foot of all of the fields and in the second of all except three at Mc Cook is negligible. The differences between fields in the same area is too great to permit of the carbon dioxide content serving as a definite area characteristic although it distinguishes the subsoils of the eastern portion of the loess from those of the central and western portions.

MAGNESIA

The magnesia (Table VIII) shows no definite relation to the lime. The total varies but little from east to west and, except that it is lowest in the surface foot, shows no dependence upon the depth. In the most easterly two areas it is equal in amount to, or even higher than, the lime, but in the others it is much lower. The acid-soluble portion, except that it also is lowest in the surface foot, shows no dependence upon either the depth or the aridity of climate.

TABLE VII

CARBON DIOXIDE IN THE FOOT-SECTIONS FROM DIFFERENT FIELDS IN THE WESTERLY AREAS

Depth Foot	Field I %	Field II %	Field III %	Field IV %	Field V %	Average %
			WAUNETA			
3	.77	.17	.35	.11	1.25	.53
4	1.77	1.68	1.14	1.73	2.00	1.66
5	1.77	1.01	1.76	1.90	2.11	1.71
6	2.00	1.18	1.56	1.44	2.04	1.64
			McCOOK.			
2	.37	.09	.42	.09	1.05	.40
3	1.78	.71	2.04	1.54	3.45	1.90
4	1.95	1.83	2.57	1.84	3.05	2.25
5	1.93	1.99	2.16	1.74	2.50	2.06
6	1.99	1.72	2.11	1.61	2.35	1.96
			HOLDREGE.			
4	.67	1.16	.45	.42	.33	.61
5	1.15	1.22	.71	1.06	.40	.91
6	1.17	1.19	.91	1.19	.62	1.01

Five-gram portions of the Wauneta and Lincoln samples were warmed with dilute (1 to 5) hydrochloric acid for 5 minutes in order to decompose the carbonates. The acid extract was then quickly filtered off, the residue washed and the lime and magnesia determined in the filtrate, in which would be found all of these two bases present in the soil in the form of carbonates, together with some derived from readily decomposable silicates (Table IX).

From the eastern, practically carbonate-free soils at Lincoln, the amount of magnesia dissolved is almost equal to that of the lime, while from the strongly effervescing subsoils at Wauneta more than twice as much lime as magnesia is dissolved. As there is more than enough readily soluble lime to account for all the carbon dioxide, evidently but a small portion of the carbonates, at most, consists of dolomite or magnesite.

ALUMINA

The total alumina (Table X) is very uniformly distributed, it showing a maximum of 14.04, and a minimum of 10.88, with an average of 12.19 per cent. There is a slight decrease from east to west but this may be attributed to the leaching out of the calcium carbonate in the easterly

TABLE VIII

MAGNESIA IN THE FOOT-SECTIONS

Depth Foot	Wauneta %	McCook %	Holdrege %	Hastings %	Lincoln %	W. Water %	Average %
TOTAL							
1	1.05	1.15	.90	.85	1.02	.88	.97
2	1.30	1.34	1.16	1.07	1.21	1.27	1.22
3	1.46	1.58	1.22	1.23	1.18	1.57	1.37
4	1.49	1.59	1.53	1.32	1.33	1.35	1.43
5	1.36	1.45	1.43	1.34	1.21	1.28	1.35
6	1.51	1.50	1.48	1.39	1.32	1.33	1.42
Average	1.36	1.43	1.29	1.20	1.21	1.28	1.29
ACID-SOLUBLE							
1	.83	.98	.81	.69	.76	.80	.81
2	.92	1.27	1.00	.80	.85	1.03	.98
3	.97	1.41	1.12	1.07	.93	1.12	1.10
4	.90	1.49	1.25	1.12	.88	1.01	1.11
5	1.04	1.41	1.32	1.16	.93	.94	1.13
6	1.01	1.43	1.32	1.23	.72	1.19	1.15
Average	.94	1.33	1.14	1.01	.84	1.01	1.05
ACID-INSOLUBLE							
1	.22	.17	.09	.16	.26	.08	.16
2	.38	.07	.16	.27	.36	.24	.24
3	.49	.17	.10	.16	.25	.45	.27
4	.59	.10	.28	.20	.45	.34	.32
5	.32	.04	.11	.18	.28	.34	.21
6	.49	.07	.16	.16	.60	.14	.27
Average	.42	.10	.15	.19	.37	.26	.24

TABLE IX

RELATIVE AMOUNTS OF LIME AND MAGNESIA DISSOLVED BY DILUTE HYDROCHLORIC ACID FROM SEMI-ARID AND HUMID SOILS

Depth Foot	Wauneta		Lincoln	
	CaO %	MgO %	CaO %	MgO %
1	.42	.59	.36	.26
2	.48	.64	.39	.34
3	1.20	.69	.44	.38
4	2.35	.87	.48	.42
5	2.36	.91	.60	.45
6	2.32	.90	.49	.35
Average	1.52	.76	.46	.36

areas with a consequent concentration of the other constituents. In each area the first foot-sample contains less than the second but in the most westerly fields this difference is slight. This is to be attributed to the carrying of colloidal clay from the first foot into the lower levels. The acid-soluble portion is similar in the western four areas, but distinctly higher at Lincoln and Weeping Water. It also is lower in the first than in the second foot. The larger proportion of acid-soluble alumina in the Lincoln and Weeping Water areas may be attributed to the higher content of clay in these soils, the alumina in the latter being more readily soluble than that in the coarser fractions.

TABLE X

ALUMINA IN THE FOOT-SECTIONS

Depth Foot	Wauneta %	McCook %	Holdrege %	Hastings %	Lincoln %	W. Water %	Average %
			TOTAL				
1	11.32	11.33	10.88	11.05	11.43	11.57	11.26
2	11.80	11.73	12.75	12.52	14.04	12.81	12.61
3	11.87	11.66	12.08	13.31	13.42	12.91	12.54
4	11.91	11.43	11.54	12.18	13.00	13.20	12.21
5	11.01	11.76	11.26	12.45	13.26	13.00	12.12
6	11.17	11.86	12.76	12.80	12.94	12.76	12.38
Average	11.51	11.63	11.88	12.38	13.01	12.71	12.19
			ACID-SOLUBLE				
1	6.94	6.80	5.72	5.84	8.34	8.30	7.00
2	7.73	8.16	7.67	7.99	11.61	10.43	8.93
3	7.91	7.64	8.14	8.41	10.28	10.93	8.89
4	7.41	7.81	7.54	7.90	10.25	9.70	8.44
5	7.07	7.84	6.96	7.40	10.22	9.48	8.16
6	6.97	7.80	7.14	7.16	10.00	9.52	8.10
Average	7.34	7.67	7.19	7.45	10.12	9.73	8.25
			ACID-INSOLUBLE				
1	4.38	4.53	5.16	5.21	3.09	3.27	4.27
2	4.07	3.57	5.08	4.53	2.43	2.38	3.68
3	3.96	4.02	3.94	4.90	3.14	1.98	3.66
4	4.50	3.62	4.00	4.28	2.75	3.50	3.77
5	3.94	3.92	4.30	5.05	3.04	3.52	3.96
6	4.20	4.06	5.62	5.64	2.94	3.24	4.28
Average	4.17	3.96	4.69	4.93	2.89	2.98	3.93

Hall and Russell (10, p. 217) in an exhaustive study of a large number of English soils, have found close relationship between the clay content and the proportion of both potash and alumina dissolved by 48 hours' digestion on the water-bath with hydrochloric acid of 1.115 specific gravity. They included in clay only the particles below .002 mm. in diameter, while we include also those between .002 and .005 mm. They found the alumina commonly to amount to about one-third of the clay fraction and to ten times the potash. We find no relation between the potash and the

alumina (Tables XIX to XXIV); in the western areas the alumina equals the clay, and in the eastern it is more than half as high. If we had excluded the fraction between .002 and .005 mm. the ratio would have been still higher.

TABLE XI

FERRIC OXIDE IN THE FOOT-SECTIONS

Depth Foot	Wauneta %	McCook %	Holdrege %	Hastings %	Lincoln %	W. Water %	Average %
			TOTAL				
1	3.07	3.55	3.13	2.91	3.71	4.24	3.43
2	3.39	4.00	3.70	4.07	4.52	5.10	4.13
3	3.46	3.71	4.00	4.14	5.00	5.25	4.26
4	3.36	3.75	3.86	4.03	5.03	5.03	4.18
5	3.24	3.55	3.83	4.00	4.81	4.77	4.03
6	3.17	3.48	3.52	3.85	4.81	4.93	3.96
Average	3.28	3.67	3.67	3.83	4.65	4.89	4.00
			ACID-SOLUBLE				
1	2.92	3.29	2.94	2.84	3.50	4.08	3.26
2	3.22	3.48	3.53	3.75	4.32	4.78	3.85
3	3.13	3.47	3.56	3.93	4.50	4.85	3.91
4	3.19	3.27	3.46	3.73	4.43	4.73	3.80
5	3.10	3.31	3.38	3.69	4.40	4.59	3.74
6	2.91	3.10	3.36	3.65	4.31	4.63	3.66
Average	3.08	3.32	3.37	3.60	4.24	4.61	3.70
			ACID-INSOLUBLE				
1	.15	.26	.19	.07	.21	.16	.17
2	.17	.52	.17	.32	.20	.32	.28
3	.33	.24	.44	.21	.50	.40	.35
4	.17	.48	.40	.30	.60	.30	.38
5	.14	.24	.45	.31	.41	.18	.29
6	.26	.38	.16	.20	.50	.30	.30
Average	.20	.35	.30	.23	.40	.28	.29

IRON

The iron is reported as ferric oxide (Table XI), no attempt having been made to determine the ferrous iron on account of the large amount of organic matter in the surface soils. The total amount is about 1 per cent higher in the Weeping Water and Lincoln areas than in those to the west. Like the alumina it is lower in the first than in the second foot, but the relative differences are much greater. While in most of the areas the ferric oxide and alumina show much similarity in distribution they do not reach their maxima in the same levels. The amounts of ferric oxide in the levels below the first foot are very similar, although the maximum usually is found in the third or fourth foot. At the end of 5 days' digestion with hydrochloric acid less than one-tenth of the iron remains undissolved, the proportion being independent of both depth and relative aridity. The subsoils from the Weeping Water and Lincoln areas, those in

which we find the highest proportion of iron, have a more distinctly yellow color. Without suggesting a cause for the higher iron content of these two areas it may be pointed out that they are underlaid by the highly ferruginous Kansan till and Dakota sandstone, neither of which underlies the loess of any of the other areas.

TABLE XII

SILICA IN THE DIFFERENT FOOT-SECTIONS

Depth Foot	Wauneta %	McCook %	Holdrege %	Hastings %	Lincoln %	W. Water %	Average %
1	72.98	72.10	71.88	72.58	69.81	69.95	71.55
2	72.70	70.88	70.75	70.39	67.78	68.10	70.10
3	71.24	68.35	70.68	70.72	69.46	68.95	69.90
4	69.28	68.22	70.21	70.27	70.49	70.38	69.81
5	70.98	68.82	70.68	71.15	70.53	70.28	70.41
6	70.57	69.47	70.77	71.15	70.71	70.61	70.55
Average	71.29	69.64	70.83	71.04	69.80	69.66	70.38

TABLE XIII

DIFFERENCES IN SILICA, ALUMINA AND FERRIC OXIDE BETWEEN THE FIRST AND SECOND FEET. IN THE FIRST FOOT THE SILICA IS HIGHER BUT THE ALUMINA AND THE FERRIC OXIDE ARE LOWER

	Wauneta %	McCook %	Holdrege %	Hastings %	Lincoln %	W. Water %
SiO_2	.28	1.22	1.13	2.19	2.03	1.85
Al_2O_3	—.48	—.40	—1.87	—1.47	—2.61	—1.24
Fe_2O_3	—.32	—.45	— .57	—1.16	—0.81	—0.86

SILICA

The silica (Table XII) is practically uniform throughout. There is no distinct difference between the eastern and the western soils, and but little between the amounts in the different foot-sections. As there is an average of about 5 per cent of carbonates in the soils from the two westerly areas the proportion of silica in the carbonate-free portion is really highest in these. There is slightly more in the first than in the second foot of each of the areas. In general the greater the difference in silica shown by the two levels the greater is that in alumina, but in the opposite direction. This will be evident from Table XIII. This relation is to be attributed to the colloidal clay and ferric hydrate having been carried down from the surface and deposited in the second foot, while the sand grains were left behind.

SULPHUR

Sulphur is present in these soils probably only in the form of sulphates. The amount (Table XIV) is everywhere small and appears independent of both the depth and the relative aridity. In general a little more than half is soluble in hydrochloric acid. The differences in the amount of the insoluble portion are of no real significance. The experi-

mental errors in the determination of the small percentages of both total and acid-soluble sulphur, the data used to obtain the acid-insoluble portion, may either counterbalance one another, or, if in the same direction, double the error.

TABLE XIV

SULPHURIC ACID IN THE FOOT-SECTIONS.

TOTAL

Depth Foot	Wauneta %	McCook %	Holdrege %	Hastings %	Lincoln %	W. Water %	Average %
1	.09	.09	.08	.08	.07	.10	.08
2	.08	.09	.08	.09	.08	.10	.09
3	.06	.08	.05	.08	.10	.10	.08
4	.08	.09	.08	.06	.08	.06	.07
5	.08	.10	.09	.08	.06	.07	.08
6	.07	.09	.08	.06	.06	.05	.07
Average	.08	.09	.08	.07	.07	.08	.08

ACID-SOLUBLE

1	.03	.03	.05	.06	.05	.06	.05
2	.03	.03	.04	.04	.07	.07	.05
3	.03	.04	.04	.03	.04	.06	.04
4	.03	.04	.04	.04	.04	.04	.04
5	.03	.04	.06	.05	.05	.03	.04
6	.03	.05	.05	.05	.07	.03	.05
Average	.03	.04	.05	.05	.05	.05	.05

ACID-INSOLUBLE

1	.06	.06	.03	.02	.02	.04	.04
2	.05	.06	.04	.05	.01	.03	.04
3	.03	.04	.01	.05	.06	.04	.04
4	.05	.05	.04	.02	.04	.02	.04
5	.05	.06	.03	.03	.01	.04	.04
6	.04	.04	.03	.01	.01	.02	.03
Average	.05	.05	.03	.04	.02	.03	.04

BARYTA

The baryta, which is all insoluble (Table XV), is uniform in distribution. It is of interest that the amount of acid-insoluble SO_3 corresponds to what would be required if the whole of it were present in combination as barium sulphate.

MANGANESE

The manganese (Table XVI) is much higher in the eastern two areas than in those to the west, in this respect resembling the iron, but showing no relation to the depth.

The whole of it is soluble in hydrochloric acid.

Titanium

The total titanium oxide (Table XVII), like the iron, is highest in the easterly two areas, while the acid-soluble portion shows no distinct differences. Neither bears any relation to the depth.

TABLE XV

BARYTA IN THE FOOT-SECTIONS

TOTAL

Depth Foot	Wauneta %	McCook %	Holdrege %	Hastings %	Lincoln %	W. Water %	Average %
1	.09	.07	.07	.07	.07	.06	.07
2	.06	.07	.07	.08	.07	.06	.07
3	.06	.07	.07	.08	.07	.09	.07
4	.06	.08	.09	.07	.07	.06	.07
5	.06	.08	.09	.07	.07	.09	.07
6	.05	.08	.06	.07	.08	.08	.07
Average	.06	.08	.08	.07	.07	.07	.07

TABLE XVI

MANGANESE OXIDE IN THE FOOT-SECTIONS

Depth Foot	Wauneta %	McCook %	Holdrege %	Hastings %	Lincoln %	W. Water %	Average %
1	.05	.06	.06	.07	.10	.11	.08
2	.05	.06	.06	.07	.10	.12	.08
3	.05	.06	.06	.07	.11	.12	.08
4	.05	.06	.06	.07	.12	.12	.08
5	.05	.06	.06	.07	.12	.12	.08
6	.05	.06	.06	.07	.12	.15	.08
Average	.05	.06	.06	.07	.11	.12	.08

The small amounts of calcium carbonate in the eastern areas may be explained on the assumption that what was originally present has been leached out, but a difference in climate would fail to account for the distinctly larger amounts of iron, titanium and manganese found in the areas overlying the Kansan drift.

Water-Soluble Material

In all the area foot-samples we determined the total amount of water-soluble material, including both organic and inorganic, by agitation with carbon dioxide-free water, filtration through a Chamberland-Pasteur filter, evaporation on the water-bath and subsequent drying at 105° C. It varied from 0.05 to 0.12 per cent, the amount present not being related to the relative aridity.

TABLE XVII
TITANIUM OXIDE IN THE FOOT-SECTIONS

Depth Foot	Wauneta %	McCook %	Holdrege %	Hastings %	Lincoln %	W. Water %	Average %
			TOTAL				
1	1.08	.98	.98	1.03	1.24	1.24	1.09
2	1.10	.98	.98	1.04	1.25	1.25	1.10
3	1.10	.98	.99	1.03	1.25	1.25	1.10
4	1.10	.98	.98	1.03	1.25	1.29	1.10
5	1.10	.98	.96	1.03	1.14	1.30	1.08
6	1.10	.98	.98	1.03	1.16	1.29	1.09
Average	1.10	.98	.98	1.03	1.21	1.27	1.09
			ACID-SOLUBLE				
1	.26	.43	.21	.32	.16	.24	.27
2	.29	.24	.29	.17	.20	.22	.23
3	.30	.23	.24	.22	.18	.23	.23
4	.22	.19	.30	.10	.22	.31	.22
5	.20	.17	.27	.22	.08	.28	.20
6	.26	.18	.28	.13	.18	.28	.22
Average	.25	.24	.26	.19	.17	.26	.23
			ACID-INSOLUBLE				
1	.82	.55	.77	.71	1.08	1.00	.82
2	.81	.74	.69	.87	1.05	1.03	.86
3	.80	.75	.75	.81	1.07	1.02	.87
4	.88	.79	.68	.93	1.03	.98	.88
5	.90	.81	.69	.81	1.06	1.02	.88
6	.84	.80	.70	.90	.98	1.01	.87
Average	.85	.74	.71	.84	1.04	1.01	.86

Reaction to Litmus

The acidity, as this term is commonly used in regard to soils, decreases from east to west. When tested with litmus the eastern soils showed a neutral and the western a slightly alkaline reaction, the intensity in the case of the latter being greater in the lower levels.

Acid-Insoluble Matter

The proportion which remains after digesting 5 days with hydrochloric acid and subsequently igniting (Table XVIII-A) is highest at Wauneta, lowest at Weeping Water and intermediate and similar in the intervening areas, except that it is higher in the first than in the second foot and shows no dependence upon the depth. However, such a presentation of the data may be somewhat misleading, as the amount of insoluble matter thus found is greatly affected by the proportion of both the organic matter and the carbonates. The relation of the insoluble matter to the non-volatile, carbonate-free portion of the samples will give us a much better idea of the variations in the sum of the silica and the insoluble silicates. This is shown in Table XVIII-B. In preparing this we cal-

culated the amount of the carbonate on the assumption that the whole of the carbon dioxide is present in the form of the calcium salt. Thus in the case of the fifth foot from Wauneta, in which there is 2.75 per cent of volatile matter and 1.78 per cent of carbon dioxide, the insoluble matter, 79.88 per cent, is derived from 93.21 per cent of non-volatile, carbonate-free material, and so forms 85.71 per cent of this. The highest amount is found at Wauneta and the lowest at Weeping Water. The Lincoln area closely resembles the latter, while Hastings, Holdrege and McCook show an intermediate composition. In all the areas the proportion of the insoluble material in the first foot is higher than in any of the underlying sections. The latter are similar. This would indicate that the leaching has somewhat affected the silicates in the surface foot, but not in the lower levels.

TABLE XVIII
ACID-INSOLUBLE MATTER

A.—IN MOISTURE-FREE SAMPLES

Depth Foot	Wauneta %	McCook %	Holdrege %	Hastings %	Lincoln %	W. Water %	Average %
1	82.28	79.98	80.77	81.11	76.65	76.07	79.48
2	81.67	78.17	78.60	78.38	74.82	74.47	77.68
3	80.77	76.04	78.63	78.22	76.61	75.50	77.63
4	79.18	76.57	78.75	78.89	77.51	76.64	77.92
5	79.88	77.19	79.43	79.65	78.01	77.82	78.66
6	79.97	77.67	79.50	79.84	78.96	78.01	78.99
Average	80.62	77.60	79.28	79.35	77.09	76.42	78.39

B.—IN NON-VOLATILE, CARBONATE-FREE PORTIONS

1	86.84	84.90	86.96	86.53	83.73	84.13	85.51
2	85.24	82.66	82.88	82.94	81.26	80.26	82.54
3	85.39	82.93	82.57	82.21	80.97	79.77	82.31
4	85.37	83.91	83.50	82.87	81.04	80.21	82.82
5	85.70	83.96	84.15	83.18	81.55	81.32	83.31
6	85.79	84.18	84.12	83.73	82.32	81.28	83.57
Average	85.72	83.76	84.03	83.58	81.81	81.16	83.34

For convenience of reference and comparison the data are summarized in Tables XIX to XXVI. The data on the volatile matter are those reported by Alway and McDole (2, p. 232) and those on potash, soda and phosphoric acid reported by Alway and Isham, (1, p. 301).

Comparison with Chernozem Soils

The *mechanical composition* of the Chernozem soils is very uniform from the surface downward and shows no definite relation to the depth (14, p. 300); this is true also of the Nebraska loess. In the case of the latter there is a little less clay in the first than in the second foot but the available data on the Chernozem do not permit of a comparison on this point.

TABLE XIX

COMPOSITION OF SOILS FROM WAUNETA AREA

COMPLETE ANALYSIS

	1st Foot %	2d Foot %	3d Foot %	4th Foot %	5th Foot %	6th Foot %	Average %
SiO_2	72.98	72.70	71.24	69.28	70.98	70.57	71.29
Al_2O_3	11.32	11.80	11.87	11.91	11.01	11.17	11.51
Fe_2O_3	3.07	3.39	3.46	3.36	3.24	3.17	3.28
MnO	.05	.05	.05	.05	.05	.05	.05
MgO	1.05	1.30	1.46	1.49	1.36	1.51	1.36
CaO	1.67	1.69	2.72	3.93	3.91	3.94	2.98
Na_2O	1.41	1.43	1.34	1.42	1.45	1.48	1.42
K_2O	2.63	2.68	2.70	2.65	2.67	2.75	2.68
TiO_2	1.08	1.10	1.10	1.10	1.10	1.10	1.10
P_2O_5	.12	.13	.12	.15	.15	.14	.13
CO_2	.09	.07	.59	1.67	1.78	1.68	.98
SO_3	.09	.08	.06	.08	.08	.07	.08
BaO	.09	.06	.06	.06	.06	.05	.06
Volatile matter	5.05	4.03	4.08	3.47	2.75	2.97	3.72
Total	100.70	100.51	100.85	100.62	100.59	100.65	100.64

DIGESTION WITH HYDROCHLORIC ACID

Insoluble	82.28	81.67	80.77	79.18	79.88	79.97	80.62
Al_2O_3	6.94	7.73	7.91	7.41	7.07	6.97	7.34
Fe_2O_3	2.92	3.22	3.13	3.19	3.10	2.91	3.08
MnO	.06	.06	.06	.06	.06	.06	.06
MgO	.83	.92	.97	.90	1.04	1.01	.94
CaO	1.10	1.15	1.81	3.06	3.04	3.43	2.26
Na_2O	.32	.37	.43	.33	.53	.43	.40
K_2O	.96	1.17	1.06	1.14	1.16	1.16	1.11
P_2O_5	.12	.12	.10	.13	.13	.12	.12
TiO_2	.26	.29	.30	.22	.20	.26	.25
CO_2	.09	.07	.59	1.67	1.78	1.68	.98
SO_3	.03	.03	.03	.03	.03	.03	.03
Volatile matter	5.05	4.03	4.08	3.47	2.75	2.97	3.72
Total	100.96	100.83	101.24	100.79	100.77	101.00	100.91

ACID-INSOLUBLE PORTION

SiO_2	72.98	72.70	71.24	69.28	70.98	70.57	71.29
Al_2O_3	4.38	4.07	3.96	4.50	3.94	4.20	4.17
Fe_2O_3	.15	.17	.33	.27	.14	.26	.22
MnO	.00	.00	.00	.00	.00	.00	.00
MgO	.22	.38	.49	.59	.32	.49	.42
CaO	.57	.54	.91	.87	.87	.51	.72
Na_2O	1.09	1.06	.91	1.09	.92	1.05	1.02
K_2O	1.67	1.51	1.64	1.51	1.51	1.59	1.57
P_2O_5	.00	.01	.02	.02	.02	.02	.01
TiO_2	.82	.81	.80	.88	.90	.84	.85
SO_3	.06	.05	.03	.05	.05	.04	.05
BaO	.09	.06	.06	.06	.06	.06	.06
Total	82.03	81.36	80.39	79.22	79.81	79.63	80.38

TABLE XX

COMPOSITION OF SOILS FROM McCOOK AREA

COMPLETE ANALYSIS

	1st Foot %	2d Foot %	3d Foot %	4th Foot %	5th Foot %	6th Foot %	Average %
SiO_2	72.10	70.88	68.35	68.22	68.82	69.47	69.64
Al_2O_3	11.33	11.73	11.66	11.43	11.76	11.86	11.63
Fe_2O_3	3.55	4.00	3.71	3.75	3.55	3.48	3.67
MnO	.06	.06	.06	.06	.06	.06	.06
MgO	1.15	1.34	1.58	1.59	1.45	1.50	1.43
CaO	1.40	1.80	3.59	3.91	3.54	3.44	2.95
Na_2O	1.50	1.49	1.40	1.36	1.51	1.50	1.46
K_2O	2.51	2.49	2.50	2.55	2.63	2.60	2.55
TiO_2	.98	.98	.98	.98	.98	.98	.98
P_2O_5	.13	.12	.12	.12	.13	.13	.12
CO_2	.02	.40	2.02	2.34	2.11	2.08	1.49
SO_3	.09	.09	.08	.09	.10	.09	.09
BaO	.07	.07	.07	.08	.08	.08	.08
Volatile matter	5.71	4.52	3.74	3.44	3.28	3.00	3.95
Total	100.60	99.97	99.86	99.92	100.00	100.27	100.10

DIGESTION WITH HYDROCHLORIC ACID

Insoluble	79.98	78.17	76.04	76.57	77.19	77.67	77.60
Al_2O_3	6.80	8.16	7.64	7.81	7.84	7.80	7.67
Fe_2O_3	3.29	3.48	3.47	3.27	3.31	3.10	3.32
MnO	.06	.06	.06	.06	.06	.06	.06
MgO	.98	1.27	1.41	1.49	1.41	1.43	1.33
CaO	.88	1.38	3.03	3.33	3.04	2.84	2.42
Na_2O	.47	.41	.49	.45	.41	.38	.43
K_2O	1.15	1.23	1.27	1.22	1.21	1.22	1.22
P_2O_5	.12	.11	.11	.10	.10	.11	.11
TiO_2	.43	.24	.23	.19	.17	.18	.24
CO_2	.02	.40	2.02	2.34	2.11	2.08	1.49
SO_3	.03	.03	.04	.04	.04	.05	.04
Volatile matter	5.70	4.52	3.74	3.44	3.28	3.00	3.95
Total	99.91	99.46	99.55	100.31	100.17	99.92	99.88

ACID-INSOLUBLE PORTION

SiO_2	72.10	70.88	68.35	68.22	68.82	69.47	69.64
Al_2O_3	4.53	3.57	4.02	3.62	3.92	4.06	3.96
Fe_2O_3	.26	.52	.24	.48	.24	.38	.35
MnO	.00	.00	.00	.00	.00	.00	.00
MgO	.17	.07	.17	.10	.04	.07	.10
CaO	.52	.42	.56	.58	.50	.60	.53
Na_2O	1.03	1.08	.91	.91	1.10	1.12	1.03
K_2O	1.36	1.26	1.23	1.33	1.42	1.38	1.33
P_2O_5	.01	.01	.01	.02	.03	.02	.01
TiO_2	.55	.74	.75	.79	.81	.80	.74
SO_3	.06	.06	.04	.05	.06	.04	.05
BaO	.07	.07	.07	.08	.08	.08	.07
Total	80.66	78.68	76.35	76.18	77.02	78.02	77.81

TABLE XXI

COMPOSITION OF SOILS FROM HOLDREGE AREA

COMPLETE ANALYSIS

	1st Foot %	2d Foot %	3d Foot %	4th Foot %	5th Foot %	6th Foot %	Average %
SiO_2	71.88	70.75	70.68	70.21	70.68	70.77	70.83
Al_2O_3	10.88	12.75	12.08	11.54	11.26	12.76	11.88
Fe_2O_3	3.13	3.70	4.00	3.86	3.83	3.52	3.67
MnO	.06	.06	.06	.06	.06	.06	.06
MgO	.90	1.16	1.22	1.53	1.43	1.48	1.29
CaO	1.18	1.33	1.60	2.15	2.30	2.19	1.79
Na_2O	1.50	1.38	1.40	1.44	1.57	1.49	1.46
K_2O	2.40	2.46	2.56	2.67	2.64	2.66	2.36
TiO_2	.98	.98	.99	.98	.96	.98	.98
P_2O_5	.14	.11	.13	.15	.13	.11	.13
CO_2	.01	.03	.13	.75	1.00	1.05	.49
SO_3	.08	.08	.05	.08	.09	.08	.08
BaO	.07	.07	.07	.09	.09	.06	.08
Volatile matter	7.10	5.10	4.48	3.98	3.34	3.10	4.52
Total	100.31	99.96	99.45	99.49	99.38	100.31	99.82

DIGESTION WITH HYDROCHLORIC ACID

Insoluble	80.77	78.60	78.63	78.75	79.43	79.50	79.28
Al_2O_3	5.72	7.67	8.14	7.54	6.96	7.14	7.19
Fe_2O_3	2.94	3.53	3.56	3.46	3.38	3.36	3.37
MnO	.05	.05	.05	.05	.05	.05	.05
MgO	.81	1.00	1.12	1.25	1.32	1.32	1.14
CaO	.74	.86	.97	1.69	1.84	1.84	1.32
Na_2O	.32	.42	.50	.50	.45	.47	.44
K_2O	1.13	1.35	1.33	1.36	1.32	1.32	1.30
P_2O_5	.11	.10	.13	.14	.13	.09	.12
TiO_2	.21	.29	.24	.30	.27	.28	.26
CO_2	.01	.03	.13	.75	1.00	1.05	.49
SO_3	.05	.04	.04	.04	.06	.05	.05
Volatile matter	7.10	5.10	4.48	3.98	3.34	3.10	4.52
Total	99.96	99.04	99.32	99.81	99.55	99.57	99.53

ACID-INSOLUBLE PORTION

SiO_2	71.88	70.75	70.68	70.21	70.68	70.77	70.83
Al_2O_3	5.16	5.08	3.94	4.00	4.30	5.62	4.69
Fe_2O_3	.19	.17	.44	.40	.45	.16	.30
MnO	.01	.01	.01	.01	.01	.01	.01
MgO	.09	.16	.10	.28	.11	.16	.15
CaO	.44	.47	.63	.46	.46	.35	.47
Na_2O	1.18	.96	.90	.94	1.12	1.02	1.02
K_2O	1.27	1.11	1.23	1.31	1.32	1.34	1.26
P_2O_5	.03	.01	.00	.01	.00	.02	.01
TiO_2	.77	.69	.75	.68	.69	.70	.71
SO_3	.03	.04	.01	.04	.03	.03	.03
BaO	.07	.07	.07	.09	.09	.06	.07
Total	81.12	79.52	78.76	78.43	79.26	80.24	79.55

TABLE XXII

COMPOSITION OF SOILS FROM HASTINGS AREA

COMPLETE ANALYSIS

	1st Foot %	2d Foot %	3d Foot %	4th Foot %	5th Foot %	6th Foot %	Average %
SiO_2	72.58	70.39	70.72	70.27	71.15	71.15	71.04
Al_2O_3	11.05	12.52	13.31	12.18	12.45	12.80	12.39
Fe_2O_3	2.91	4.07	4.14	4.03	4.00	3.85	3.83
MnO	.07	.07	.07	.07	.07	.07	.07
MgO	.85	1.07	1.23	1.32	1.34	1.39	1.20
CaO	1.13	1.16	1.45	1.75	1.80	1.72	1.50
Na_2O	1.48	1.36	1.36	1.59	1.47	1.54	1.47
K_2O	2.49	2.45	2.51	2.56	2.67	2.65	2.55
TiO_2	1.03	1.04	1.03	1.03	1.03	1.03	1.03
P_2O_5	.11	.11	.12	.11	.13	.15	.12
CO_2	.01	.02	.10	.36	.38	.41	.21
SO_3	.08	.09	.08	.06	.08	.06	.07
BaO	.07	.08	.08	.07	.07	.07	.07
Volatile matter	6.25	5.45	4.63	4.00	3.83	3.71	4.64
Total	100.11	99.88	100.83	99.40	100.47	100.60	100.18

DIGESTION WITH HYDROCHLORIC ACID

Insoluble	81.11	78.38	78.22	78.89	79.65	.79.84	79.35
Al_2O_3	5.84	7.99	8.41	7.90	7.40	7.16	7.45
Fe_2O_3	2.84	3.75	3.93	3.73	3.69	3.65	3.60
MnO	.05	.05	.06	.04	.04	.04	.05
MgO	.69	.80	1.07	1.12	1.16	1.23	1.01
CaO	.68	.74	.97	1.22	1.33	1.36	1.05
Na_2O	.48	.45	.46	.54	.46	.42	.47
K_2O	1.15	1.42	1.46	1.36	1.38	1.35	1.35
P_2O_5	.10	.11	.12	.10	.13	.13	.11
TiO_2	.32	.17	.22	.10	.22	.13	.19
CO_2	.01	.02	.10	.36	.38	.41	.21
SO_3	.06	.04	.03	.04	.05	.05	.05
Volatile matter	6.25	5.45	4.63	4.00	3.83	3.71	4.64
Total	99.58	99.37	99.68	99.40	99.72	99.48	99.53

ACID-INSOLUBLE PORTION

SiO_2	72.58	70.39	70.72	70.27	71.15	71.15	71.04
Al_2O_3	5.21	4.53	4.90	4.28	5.05	5.64	4.93
Fe_2O_3	.07	.32	.21	.30	.31	.20	.23
MnO	.02	.02	.01	.03	.03	.03	.02
MgO	.16	.27	.16	.20	.18	.16	.19
CaO	.45	.42	.48	.53	.47	.36	.45
Na_2O	1.00	.91	.90	1.05	1.01	1.12	1.00
K_2O	1.34	1.03	1.05	1.20	1.29	1.30	1.20
P_2O_5	.01	.00	.00	.01	.00	.02	.01
TiO_2	.71	.87	.81	.93	.81	.90	.84
SO_3	.02	.05	.05	.02	.03	.01	.03
BaO	.07	.08	.08	.07	.07	.07	.07
Total	81.64	78.88	79.37	78.89	80.40	80.92	80.01

TABLE XXIII

COMPOSITION OF SOILS FROM LINCOLN AREA

COMPLETE ANALYSIS

	1st Foot %	2d Foot %	3d Foot %	4th Foot %	5th Foot %	6th Foot %	Average %
SiO_2	69.81	67.78	69.46	70.49	70.53	70.71	69.80
Al_2O_3	11.43	14.04	13.42	13.00	13.26	12.94	13.01
Fe_2O_3	3.71	4.52	5.00	5.03	4.81	4.81	4.65
MnO	.10	.10	.11	.12	.12	.12	.11
MgO	1.02	1.21	1.18	1.33	1.21	1.32	1.21
CaO	.72	1.00	1.21	1.21	1.39	1.31	1.14
Na_2O	.96	.94	1.06	1.14	1.21	1.18	1.08
K_2O	2.46	2.47	2.51	2.54	2.52	2.53	2.50
TiO_2	1.24	1.25	1.25	1.25	1.14	1.16	1.21
P_2O_5	.13	.14	.16	.17	.19	.17	.16
CO_2	.01	.02	.02	.06	.12	.08	.05
SO_3	.07	.08	.10	.08	.06	.06	.07
BaO	.07	.07	.07	.07	.07	.08	.07
Volatile matter	8.44	6.68	5.25	4.22	4.07	3.90	5.43
Total	100.17	100.30	100.80	100.71	100.70	100.37	100.49

DIGESTION WITH HYDROCHLORIC ACID

Insoluble	76.65	74.82	76.61	77.51	78.01	78.96	77.09
Al_2O_3	8.34	11.61	10.28	10.25	10.22	10.00	10.12
Fe_2O_3	3.50	4.32	4.50	4.43	4.40	4.31	4.24
MnO	.09	.09	.10	.09	.09	.09	.09
MgO	.76	.85	.93	.88	.93	.72	.84
CaO	.61	.64	.75	.90	1.10	.96	.83
Na_2O	.39	.45	.43	.51	.48	.46	.45
K_2O	1.09	1.14	1.16	1.26	1.29	1.27	1.20
P_2O_5	.11	.12	.11	.14	.13	.14	.12
TiO_2	.16	.20	.18	.22	.08	.18	.17
CO_2	.01	.02	.02	.06	.12	.08	.05
SO_3	.05	.07	.04	.04	.05	.07	.05
Volatile matter	8.44	6.68	5.25	4.22	4.07	3.90	5.43
Total	100.20	101.01	100.36	100.51	100.97	101.14	100.68

ACID-INSOLUBLE PORTION

SiO_2	69.81	67.78	69.46	70.49	70.53	70.71	69.80
Al_2O_3	3.09	2.43	3.14	2.75	3.04	2.94	2.89
Fe_2O_3	.21	.20	.50	.60	.41	.50	.40
MnO	.02	.02	.01	.03	.03	.03	.02
MgO	.26	.36	.25	.45	.28	.60	.37
CaO	.11	.36	.46	.31	.29	.35	.31
Na_2O	.57	.49	.63	.63	.73	.72	.63
K_2O	1.37	1.33	1.35	1.28	1.23	1.26	1.30
P_2O_5	.02	.02	.05	.03	.06	.03	.03
TiO_2	1.08	1.05	1.07	1.03	1.06	.98	1.04
SO_3	.02	.01	.06	.04	.01	.01	.02
BaO	.07	.07	.07	.07	.07	.08	.07
Total	76.63	74.12	77.05	77.71	77.74	78.21	76.88

TABLE XXIV

COMPOSITION OF SOILS FROM WEEPING WATER AREA

COMPLETE ANALYSIS

	1st Foot %	2d Foot %	3d Foot %	4th Foot %	5th Foot %	6th Foot %	Average %
SiO_2	69.65	68.10	68.95	70.38	70.28	70.61	69.66
Al_2O_3	11.57	12.81	12.91	13.20	13.00	12.76	12.71
Fe_2O_3	4.24	5.10	5.25	5.03	4.77	4.93	4.89
MnO	.11	.12	.12	.12	.12	.15	.12
MgO	.88	1.27	1.57	1.35	1.28	1.33	1.28
CaO	.89	.95	1.37	1.08	1.08	1.18	1.09
Na_2O	1.05	.99	1.04	1.29	1.27	1.37	1.17
K_2O	2.46	2.38	2.42	2.37	2.45	2.42	2.42
TiO_2	1.24	1.25	1.25	1.29	1.30	1.29	1.27
P_2O_5	.13	.12	.13	.16	.18	.17	.15
CO_2	.01	.01	.05	.00	.02	.01	.02
SO_3	.10	.10	.10	.06	.07	.05	.08
BaO	.06	.06	.09	.06	.09	.08	.07
Volatile matter	8.43	7.17	5.24	4.46	4.27	3.99	5.59
Total	100.82	100.43	100.49	100.85	100.18	100.34	100.52

DIGESTION WITH HYDROCHLORIC ACID

Insoluble	76.07	74.47	75.50	76.64	77.82	78.01	76.42
Al_2O_3	8.30	10.43	10.93	9.70	9.48	9.52	9.73
Fe_2O_3	4.08	4.78	4.85	4.73	4.59	4.63	4.61
MnO	.10	.11	.11	.12	.12	.13	.11
MgO	.80	1.03	1.12	1.01	.94	1.19	1.01
CaO	.68	.71	.76	.78	.78	.99	.78
Na_2O	.23	.26	.33	.29	.37	.33	.30
K_2O	1.25	1.42	1.43	1.37	1.38	1.37	1.37
P_2O_5	.10	.10	.11	.16	.16	.17	.13
TiO_2	.24	.22	.23	.31	.28	.28	.26
CO_2	.01	.01	.05	.00	.02	.01	.02
SO_3	.06	.07	.06	.04	.03	.03	.05
Volatile matter	8.43	7.17	5.24	4.46	4.27	3.99	5.59
Total	100.35	100.80	100.72	99.61	100.24	100.65	100.38

ACID-INSOLUBLE PORTION

SiO_2	69.65	68.10	68.95	70.38	70.28	70.61	69.66
Al_2O_3	3.27	2.38	1.98	3.50	3.52	3.24	2.98
Fe_2O_3	.16	.32	.40	.30	.18	.30	.28
MnO	.01	.01	.01	.00	.00	.02	.01
MgO	.08	.24	.45	.34	.34	.14	.26
CaO	.21	.24	.61	.30	.30	.19	.31
Na_2O	.82	.73	.71	1.00	.90	1.04	.87
K_2O	1.21	.96	.99	1.00	1.07	1.05	1.05
P_2O_5	.03	.02	.02	.00	.02	.00	.02
TiO_2	1.00	1.03	1.02	.98	1.02	1.01	1.01
SO_3	.04	.03	.04	.02	.04	.02	.03
BaO	.06	.06	.09	.06	.09	.08	.07
Total	76.54	74.12	75.27	77.88	77.76	77.70	76.55

TABLE XXV

AVERAGE COMPOSITION OF THE SOIL FROM THE DIFFERENT LEVELS

COMPLETE ANALYSIS

	1st Foot %	2d Foot %	3d Foot %	4th Foot %	5th Foot %	6th Foot %	Average %
SiO_2	71.55	70.10	69.90	69.81	70.41	70.55	70.38
Al_2O_3	11.26	12.61	12.54	12.21	12.12	12.38	12.19
Fe_2O_3	3.43	4.13	4.26	4.18	4.03	3.96	4.00
MnO	.08	.08	.08	.08	.08	.08	.08
MgO	.97	1.22	1.37	1.43	1.35	1.42	1.29
CaO	1.16	1.32	1.99	2.34	2.34	2.30	1.91
Na_2O	1.32	1.27	1.27	1.37	1.41	1.42	1.34
K_2O	2.49	2.49	2.53	2.56	2.60	2.60	2.54
TiO_2	1.09	1.10	1.10	1.10	1.08	1.09	1.09
P_2O_5	.13	.12	.13	.14	.15	.14	.13
CO_2	.02	.09	.48	.87	.90	.88	.54
SO_3	.08	.09	.08	.07	.08	.07	.08
BaO	.07	.07	.07	.07	.07	.07	.07
Volatile matter	6.82	5.49	4.57	3.92	3.59	3.44	4.64
Total	100.47	100.18	100.37	100.15	100.21	100.40	100.28

DIGESTION WITH HYDROCHLORIC ACID

Insoluble	79.48	77.68	77.63	77.92	78.66	78.99	78.39
Al_2O_3	7.00	8.93	8.89	8.44	8.16	8.10	8.25
Fe_2O_3	3.26	3.85	3.91	3.80	3.74	3.66	3.70
MnO	.07	.07	.07	.07	.07	.07	.07
MgO	.81	.98	1.10	1.11	1.13	1.15	1.05
CaO	.78	.91	1.38	1.83	1.85	1.90	1.44
Na_2O	.37	.39	.44	.44	.45	.41	.42
K_2O	1.12	1.29	1.28	1.28	1.29	1.28	1.26
P_2O_5	.11	.11	.11	.13	.13	.13	.12
TiO_2	.27	.23	.23	.22	.20	.22	.23
CO_2	.02	.09	.48	.87	.90	.88	.54
SO_3	.05	.05	.04	.04	.04	.05	.05
Volatile matter	6.82	5.49	4.57	3.92	3.59	3.44	4.64
Total	100.16	100.07	100.13	100.07	100.21	100.28	100.16

ACID-INSOLUBLE PORTION

SiO_2	71.55	70.10	69.90	69.81	70.41	70.55	70.36
Al_2O_3	4.27	3.68	3.66	3.77	3.96	4.28	3.93
Fe_2O_3	.17	.28	.35	.38	.29	.30	.29
MnO	.01	.01	.01	.01	.01	.02	.01
MgO	.16	.24	.27	.32	.21	.27	.24
CaO	.38	.41	.61	.51	.48	.39	.46
Na_2O	.95	.88	.83	.93	.96	1.01	.92
K_2O	1.37	1.20	1.25	1.28	1.31	1.32	1.28
P_2O_5	.02	.01	.02	.01	.02	.01	.02
TiO_2	.82	.86	.87	.88	.88	.87	.86
SO_3	.03	.04	.04	.04	.04	.02	.04
BaO	.07	.07	.07	.07	.07	.07	.07
Total	79.80	77.78	77.88	78.01	78.64	79.11	78.48

TABLE XXVI

AVERAGE COMPOSITION OF THE SIX FEET OF SOIL FROM THE DIFFERENT AREAS

COMPLETE ANALYSIS

	Wauneta %	McCook %	Holdrege %	Hastings %	Lincoln %	W.Water %	Average %
SiO_2	71.29	69.64	70.83	71.04	69.80	69.66	70.38
Al_2O_3	11.51	11.63	11.88	12.38	13.01	12.71	12.19
Fe_2O_3	3.28	3.67	3.67	3.83	4.65	4.89	4.00
MnO	.05	.06	.06	.07	.11	.12	.08
MgO	1.36	1.43	1.29	1.20	1.21	1.28	1.29
CaO	2.98	2.95	1.79	1.50	1.14	1.09	1.91
Na_2O	1.42	1.46	1.46	1.47	1.08	1.17	1.34
K_2O	2.68	2.55	2.56	2.55	2.50	2.42	2.54
TiO_2	1.10	.98	.98	1.03	1.21	1.27	1.09
P_2O_5	.13	.12	.13	.12	.16	.15	.13
CO_2	.98	1.49	.49	.21	.05	.02	.54
SO_3	.08	.09	.08	.07	.07	.08	.08
BaO	.06	.08	.08	.07	.07	.07	.07
Volatile matter	3.72	3.95	4.52	4.64	5.43	5.59	4.64
Total	100.64	100.10	99.82	100.18	100.49	100.52	100.28

DIGESTION WITH HYDROCHLORIC ACID

Insoluble	80.62	77.60	79.28	79.35	77.09	76.42	78.39
Al_2O_3	7.34	7.67	7.19	7.45	10.12	9.73	8.25
Fe_2O_3	3.08	3.32	3.37	3.60	4.24	4.61	3.70
MnO	.06	.06	.05	.05	.09	.11	.07
MgO	.94	1.33	1.14	1.01	.84	1.01	1.05
CaO	2.26	2.42	1.32	1.05	.83	.78	1.44
Na_2O	.40	.43	.44	.47	.45	.30	.42
K_2O	1.11	1.22	1.30	1.35	1.20	1.37	1.26
P_2O_5	.12	.11	.12	.11	.12	.13	.12
TiO_2	.25	.24	.26	.19	.17	.26	.23
CO_2	.98	1.49	.49	.21	.05	.02	.54
SO_3	.03	.04	.05	.05	.05	.05	.05
Volatile matter	3.72	3.95	4.52	4.64	5.43	5.59	4.64
Total	100.91	99.88	99.53	99.53	100.68	100.38	100.16

ACID-INSOLUBLE PORTION

SiO_2	71.29	69.64	70.83	71.04	69.80	69.66	70.36
Al_2O_3	4.17	3.96	4.69	4.93	2.89	2.98	3.93
Fe_2O_3	.20	.35	.30	.23	.40	.28	.29
MnO	.00	.00	.01	.02	.02	.01	.01
MgO	.42	.10	.15	.19	.37	.26	.24
CaO	.72	.53	.47	.45	.31	.31	.46
Na_2O	1.10	1.03	1.02	1.00	.63	.87	.92
K_2O	1.49	1.33	1.26	1.20	1.30	1.05	1.28
P_2O_5	.02	.01	.01	.01	.03	.02	.02
TiO_2	.85	.74	.71	.84	1.04	1.01	.86
SO_3	.05	.05	.03	.03	.02	.03	.04
BaO	.06	.08	.08	.07	.07	.07	.07
Total	80.38	77.82	79.56	80.01	76.88	76.55	78.48

The Chernozem soils, excluding those with appreciable amounts of carbonates, contain approximately 1.5 to 2.0 per cent of *lime*, of which usually not less than one per cent is acid-soluble (14, p. 326). The loess soils show a quite similar composition, although containing somewhat smaller amounts in the eastern areas.

In the Chernozem the *magnesia* (14, p 326), both the total and the zeolithic portion, is usually somewhat lower than the lime. In this respect the loess soils are similar except that in the eastern two areas both the total and the acid-soluble magnesia are as high as the lime.

The total *alumina* in the Chernozem soils (14, p. 326) lies between approximately 10 and 15 per cent, about half being dissolved by a 10-hour digestion on the water-bath with 10 per cent hydrochloric acid. In the total amount the loess soils are similar but the data on the acid-soluble portions are not comparable on account of the differences in the strength of acid used and the time of digestion. The amount of alumina dissolved increases steadily during the five days' digestion, which would make it probable that the two types of soils are similar in their content of zeolithic alumina.

The *iron oxide* of the Chernozem soils varies from 2 to 5 per cent and this is almost completely acid-soluble (14, p. 396); in the loess samples we found from 3 to 5 per cent, nearly all acid-soluble.

The data on sulphur in Chernozem soils Kossowitsch (14, p. 327) considers untrustworthy. It has been reported, expressed as SO_3, to vary from 0.10 to 0.30 per cent. In none of the loess samples did we find more than 0.10 per cent.

The *water-soluble material* in the Chernozem soils Kossowitsch (14, p. 327) reports as generally less than 0.10 per cent (*ca.* 0.08 per cent) of which about half consists of organic substances. The loess soils show a similar amount.

In their *reaction* toward litmus the loess soils of Nebraska resemble the Chernozem soils of which the typical representatives (14, p. 322) possess a neutral, or those of the drier portions even a faintly alkaline, reaction; by the chestnut-colored Chernozem soils the alkaline reaction is most common, while the soils of the more humid areas may show a faintly acid reaction.

Comparisons of the potash, soda and phosphoric acid have previously been made (1, p. 313).

On the basis of the mechanical composition and of the chemical composition of the inorganic portion, including the zeolithic portion, the loess soils of the Nebraska portion of the Transition Region are very similar to the Chernozem soils of Russia.

Comparison with Arid Soils

Hilgard, who first recognized the characteristic differences between humid and arid soils, has recently (12, p. 424) compared the average composition of 313 arid soils from the Pacific slope with that of 466 humid soils from the states south of the Ohio River. All determinations of the inorganic portions were made by digestion with hydrochloric acid of 1.115 specific gravity for 5 days. Hence our data on the acid-soluble portion reported in the above tables are strictly comparable with his. In Table XXVII we give Hilgard's data in comparison with ours. In the case of the latter we employ only those from the first foot samples, and use the average from adjacent areas so that we have the humid eastern portion, the distinctly semi-arid western, and finally the intermediate portion including the Hastings and Holdrege areas.

TABLE XXVII

COMPARISON OF THE TRANSITION SOILS WITH ARID AND HUMID SOILS REPORTED BY HILGARD

	Av. of Arid 313 %	Semi-arid Western areas %	Intermediate Transition areas %	Humid Eastern areas %	Av. of Humid 466 %
Insoluble	77.82	81.13	80.94	77.57	88.24
K_2O	.73	1.05	1.14	1.12	.22
Na_2O	.26	.40	.40	.31	.09
CaO	1.36	.99	.71	.65	.11
MgO	1.41	.90	.75	.78	.23
Mn_3O_4	.06	.07	.09	.14	.13
Fe_2O_3	5.75	3.10	2.89	3.79	3.13
Al_2O_3	7.89	6.87	5.78	8.32	4.30
P_2O_5	.12	.12	.11	.11	.11
SO_3	.04	.03	.05	.05	.05
CO_2	1.32	.05	.01	.01	....
Volatile	4.94	5.37	6.67	8.43	3.64

In lime and magnesia as well as in the amount of insoluble matter all the Transition soils resemble the arid soils. The same is true of potash and soda. In carbon dioxide content all resemble the humid, the carbonates, even in the distinctly semi-arid areas, having been leached out of the surface foot. In manganese the soils from the most humid eastern two areas resemble the humid soils reported by Hilgard, while those from the other four resemble the arid. This difference in manganese content which Hilgard considers too frequent to be accidental (12, p. 392) is, as he suggests, due to some obscure cause. In the other inorganic constituents no general marked difference is observed between arid and humid soils.

Thus it is evident that the surface soils from all six areas, even the most humid, resemble the strictly arid soils reported by Hilgard.

SUMMARY

The loess soils of the Nebraska portion of the Transition Region consist chiefly of very fine sand and silt which together constitute from 77 to 95 per cent of the soil mass, the remainder being chiefly clay. As we pass from east to west, the clay decreases and the relative proportions of the silt and the very fine sand change, the former decreasing and the latter increasing.

The mechanical composition shows no distinct relation to the depth except that the clay content is lower in the first than in the second foot.

The values for the hygroscopic coefficients calculated from the mechanical analyses by the formula proposed by Briggs and Shantz agree satisfactorily with those obtained by direct determination in the case of only the samples with the smallest proportion of very fine sand. However, by altering the values assigned the sands, a formula has been obtained which is applicable to the soils from all the areas.

The samples were subjected to both a complete rock analysis and to 5-day digestion with hydrochloric acid of 1.115 specific gravity. The carbon dioxide, which is present chiefly in calcium carbonate, shows greater variations than any other constituent; while low in the first two feet of all the areas, the amount in the subsoil increases markedly as we pass from east to west. The lime varies widely, both the total and the acid-soluble portion, being three times as high in the western subsoils as in the eastern. The content of magnesia shows no definite relation to that of the lime, in the eastern areas it being as high but in the western much lower; it is independent of the aridity and, except that it is lowest in the surface foot, also of the depth. The total alumina is very uniformly distributed but in all the areas shows a minimum in the surface foot. The acid-soluble portion is similar in the western four areas, but markedly higher in the eastern two; like the total it is lower in the first than in the second foot. It shows no definite relation to either the clay or the acid-soluble potash. The iron, manganese and titanium are distinctly higher in the eastern two than in the other four areas. Almost the whole of the iron is acid-soluble; like the alumina it shows a minimum in the surface foot. The whole of the manganese is acid-soluble, but only a small part of the titanium. The silica is very uniformly distributed but, in contrast to the alumina, is in each area slightly higher in the first than in the second foot. Sulphur and baryta show no dependence upon either depth or aridity. About half of the former is acid-soluble, but none of the latter. To litmus the samples are all neutral or very slightly alkaline.

The acid-insoluble matter shows no definite relation to the aridity and, except that it is higher in the first than in the second foot, none to the depth. The proportion of acid-insoluble material in the non-volatile, car-

bonate-free portion of the soil is highest in the surface foot and similar in the lower levels, as though leaching had affected the silicates of only the first foot.

In mechanical composition these loess soils show the same characteristics as the Russian Chernozem. Also, in the chemical composition of the inorganic portion, both the total and the acid-soluble, in so far as the available data permit of comparisons, there is a very marked similarity.

A comparison with the average composition of arid and humid soils, as reported by Hilgard, shows that, except in the proportions of manganese, the first foot samples of the loess soils from the most humid areas studied resemble the arid soils as much as do those from the distinctly semi-arid western areas. In the case of this one constituent the soils from the eastern areas resemble those from the humid regions reported by Hilgard. In carbonate content the subsoils from the western and intermediate areas resemble arid subsoils and those from the eastern areas the humid soils.

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STUDIES ON THE DECOMPOSITION OF CELLULOSE IN SOILS[1]

By

I. G. McBeth

Introduction

The discovery and comprehension of the biological and chemical forces relating to the decomposition of the carbohydrate materials in soils is unquestionably necessary to the solution of many problems in soil fertility and crop production. A large percentage of the carbon content of the plant residue is found as a constituent of the celluloses. These compounds, because of their refractory nature, must first be attacked by a special group of organisms. An accurate knowledge of the cultural and biochemical characteristics of the organisms involved in the transformation of cellulose into less refractory compounds is, therefore, obviously of the greatest importance.

Extensive investigations during the last few years have shown that the decomposition of cellulose is by no means limited to the bacteria of soils. The filamentous fungi possessing this power are very numerous and many species are exceedingly active agents in the destruction of cellulose. In the humid soils of the East the filamentous fungi are perhaps of greater importance than bacteria in the destruction of cellulose, while in the semi-arid soils of the West the reverse is apparently true. Several species of Actinomyces are also known to have the power of dissolving cellulose and because of their general distribution, these organisms are undoubtedly a factor in the destruction of cellulose in soils. This paper deals, for the most part, with investigations of cellulose-dissolving bacteria.

Culture Media

Methods for the preparation of cellulose agar and other suitable culture media for the study of cellulose-dissolving bacteria have been discussed, at some length, in earlier publications by Kellerman and McBeth (29), McBeth and Scales (43), Löhnis and Lochhead (40), Kellerman,

[1] Paper No. 16, Citrus Experiment Station, College of Agriculture, University of California, Riverside, California.

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A bibliography of the literature relating to cellulose destruction is included and reference is made by numbers to "literature cited" (p. 481).

McBeth, Scales, and Smith (30), and Scales (71). The cellulose agar prepared as described in the above mentioned publications has given very satisfactory results not only with cellulose-dissolving bacteria, but also with filamentous fungi. The medium also appears to be well adapted to the study of cellulose destruction by species of Actinomyces. We have frequently observed colonies of Actinomyces which dissolve the cellulose very rapidly in the cellulose agar, forming a clear enzymic zone about the colony which furnishes unmistakable evidence of the cellulose-dissolving power of the organism. Krainsky (36) in his recent studies of the Actinomyces, has reported the cellulose agar plate method as unsatisfactory for determining the cellulose-dissolving power of these organisms. However, he was able to demonstrate the cellulose-dissolving power of several species of Actinomyces by the use of paper pulp or strips of paper on silica jelly, and also by means of cellulose hydrate prepared by the zinc chloride method. The reason for the failure of Krainsky to secure satisfactory results with the cellulose agar plate method is not clear. However, since these organisms grew luxuriantly upon the cellulose agar prepared by us and dissolved the cellulose very rapidly, it would seem that the unsatisfactory results reported by Krainsky may be due to certain inattention to details in the preparation of the cellulose precipitate. In order to secure a uniformly fine amorphous precipitate, it is necessary to carry out the operations with considerable care. It is believed that much of the difficulty experienced in the preparation of precipitated cellulose is caused by precipitating in solutions that are too concentrated. If either the copper-ammonium-cellulose solution or the acid used in precipitating the cellulose is too concentrated, a product is frequently secured which is not only difficult to wash, but is very unsatisfactory as a culture medium. A very uniform and satisfactory amorphous precipitate can be secured by adhering strictly to the following method which is a slight modification of the method originally proposed.

1. Pour 1 liter of ammonium hydroxide, sp. gr. 0.90, into a glass-stoppered bottle; add 250 c.c. of distilled water and 75 gm. of pure copper carbonate; shake the solution vigorously until all the copper is dissolved. (From 10 to 15 minutes is ordinarily required.)

2. To the copper-ammonium solution add 15 gm. of high grade, sheet filter paper; shake vigorously at intervals of 10 minutes for one-half hour. Examine the solution carefully to see that the paper is completely dissolved. If any particles of paper remain in the solution, the shaking must be continued until the solution is perfectly clear.

Dilute 250 c.c. of the ammonium-copper-cellulose solution to 10 liters with tap water; add slowly with frequent shaking, a weak hydrocloric acid solution prepared by adding 500 c.c. of concentrated acid to 10 liters of

tap water. Continue the addition of the acid until the blue color disappears; add a slight excess of acid, shake thoroughly and allow to stand a few minutes. The finely precipitated cellulose will rise to the top, due to the large quantity of free hydrogen liberated in the precipitation process. Shake the solution vigorously at intervals of a few minutes to dislodge the hydrogen. As soon as the free hydrogen has escaped the cellulose will settle rapidly.

3. Wash through repeated changes of water until free from copper and chlorine. After the washing is complete, bring the cellulose in the solution up to 0.5 per cent, by allowing to settle a few days and siphoning off the clear solution or by evaporating. Add the nutrient salts desired together with 1 per cent of thoroughly washed agar; heat in autoclave or boil until the agar is dissolved; tube and sterilize in the usual way.

Action of the Cellulose-Dissolving Bacteria Studied on the Cellulose of Plant Tissues

While the preparation of cellulose agar from precipitated cellulose as described above has proven quite satisfactory for the isolation and study of organisms which dissolve typical cellulose, such as is found in filter paper or in cotton fiber, it does not make possible a study of the action of the organisms on the celluloses in plant tissues such as are ordinarily added to the soil, as stubble, roots, green manure, etc. Since the term "cellulose" connotes a group of substances rather than a single chemical compound, it seems important that methods be devised which will make possible a comparative study of the action of the cellulose-dissolving organisms isolated from the soil, upon the cellulose of different plants and also of the same plants at different stages of maturity. In the young plant cells the walls contain almost pure cellulose, but as the plant developes the cellulose originally formed is altered by the addition to it of various secondary products known as encrusting substances. The nature and properties of the resulting fiber depends, of course, upon the nature of the substances deposited.

Since many of the cellulose-dissolving organisms attack not only the celluloses, but many other plant substances such as the starches, sugars, and proteins, it is necessary in studying the action of these organisms on the cellulose of different plant tissues, other than that of cotton fiber, to separate the cellulose from the other compounds with which it is more or less closely associated in the plant. It is also important that the purified cellulose be separated into very fine particles such as will permit the preparation of a satisfactory cellulose agar. Finely divided pure cellulose suitable for the preparation of cellulose agar may be prepared from plant substances as follows:

1. Grind a quantity of the dry plant substance to a flour and sift through bolting cloth to remove all coarse material.

2. Boil 50 gm. of the sifted flour in a 2 per cent potassium hydrate solution for one-half hour; pour into a large bottle or carboy and wash through repeated changes of water until free from potassium.

3. Expose the washed material to the action of chlorine at ordinary temperatures for one-half hour. Wash as before until the chlorine is removed.

4. Subject to a second alkaline hydrolysis by boiling with 2 per cent caustic soda for one-half hour. Wash until the solution is no longer alkaline.

The cellulose is thus isolated in a very pure state, and if the grinding of the plant material has been sufficiently fine, the finely divided cellulose prepared in this way is quite as satisfactory for the preparation of cellulose agar as that prepared from filter paper by the ordinary method.

In the present work it has not been possible to make an extensive study of the decomposition of the celluloses in different plant substances. However, it has been demonstrated that the cellulose-dissolving bacteria isolated from soils by means of the cellulose agar plate method, have the power of dissolving the cellulose of alfalfa. Twenty-five species of cellulose-dissolving bacteria were plated to cellulose agar containing pure cellulose from the alfalfa plant and in every instance the cellulose was dissolved as readily as that prepared from filter paper by the ordinary method.

Discussion of General Characteristics of Cellulose-Dissolving Bacteria

The author's exhaustive studies of a large number of soils from widely separated regions have shown that there are numerous species of bacteria which have the power to destroy cellulose. All of the forms studied are rod-shaped organisms varying in length from .8 to 3.50 μ. Involution forms have been observed for only three species. Five species have been found to produce spores. Twenty-seven of the thirty-six species isolated are motile. The arrangement of the flagella on the motile forms shows that seven species belong to the genus Pseudomonas and twenty to the genus Bacillus. All species stain readily with the aniline dyes. All are facultative in nature, but invariably develop most rapidly under aerobic conditions. With some species, the development under anaerobic conditions is very slow. All species grow well from 20° to 37.5° C., and some forms have been found to develop at temperatures as high as 45° C., but much more slowly than at the lower temperatures. The optimum temperature for most species seems to lie between 28° to 33° C.

With two exceptions, the cellulose-destroying bacteria form more or less growth upon ordinary culture media such as beef gelatin, beef agar,

etc. Of the thirty-four species which grow upon gelatin, nineteen liquefy the gelatin. Many forms produce a growth upon beef agar and potato agar slopes in 24 hours. A few species grow quite luxuriantly upon potato cylinders, but in most cases no growth or only a scant growth is produced, even when the cultures are held in a moist chamber for 30 days. Twenty-nine species produce an acid reaction and three an alkaline reaction in litmus milk. Four species do not change the reaction of litmus milk. The milk is coagulated or digested by only six species.

The destruction of cellulose can be secured in nutrient solutions containing ammonium sulphate, potassium nitrate, peptone, casein, or asparagin as the source of nitrogen. Peptone appears to give the best results for the largest number of organisms, while casein is least satisfactory for many forms. No destruction of cellulose has been secured without the addition of combined nitrogen to the nutrient solution. This would seem to indicate that the cellulose-dissolving organisms do not draw freely upon the free nitrogen of the air for their nitrogen supply. This hypothesis is further strengthened by the behavior of the organisms in dextrose solutions. When dextrose is added to nutrient solutions containing combined nitrogen, many of the cellulose-dissolving organisms vigorously attack the dextrose; but when the nutrient solution is carefully freed from combined nitrogen the dextrose is attacked very slowly and little or no fixation of nitrogen is secured.

No gas is formed by any of the species in cellulose or other carbohydrate broths. The quantity of acid produced in carbohydrate broths is fairly constant for the species, but quite variable for different species. With dextrose, lactose, maltose, saccharose, and starch the quantity of acid produced in 12 days at 30° C. usually lies between 1 and 2 per cent on Fuller's Scale. The amount of acidity in the mannite and glycerine solutions is very generally less than 1 per cent, and in many cases no acidity is produced in these solutions. Two species cause no change in the reaction of any of the carbohydrate broths. *B. rossicus* gave an alkaline reaction in all the broths, while *Ps. effusa* gave an alkaline reaction in the lactose and saccharose broths. The alkaline reaction is probably due to the formation of ammonia from the peptone in the solution, the ammonia produced being more than sufficient to neutralize any acid formed. In Dunham's solution fourteen species produce ammonia, while twenty forms produce a compound which gives typical reactions for nitrites with the Griess' reagent and also with the starch-iodide and the diphenylamine solutions. There seems to be no reason for concluding that the substance is not nitrite except that nitrite formation has been thought to be restricted to a particular group of organisms which do not grow upon ordinary media. The quantity of nitrite formed by the cellulose-dissolving forms is small; in most instances not more than one

part per million of nitrogen as nitrite is produced. However, the formation of this small amount is constant and is, therefore, of considerable value as a diagnostic feature.

Since many species produce nitrites in Dunham's solution, it is obvious that erroneous conclusions might be drawn from the use of a nitrate broth containing peptone. Peptone has therefore been left out of the nitrate broth used in studying the nitrate reducing power of these organisms; and a small quantity of starch added to furnish the necessary carbon. In this broth many of the species reduce nitrates to nitrites, but only four forms reduce nitrates to ammonia.

The Occurrence and Activity of Cellulose-Dissolving Bacteria in Southern California Soils

Examinations of 69 soils of southern California for cellulose-dissolving bacteria indicate that these soils contain numerous species of bacteria which have the power of dissolving cellulose. All of the soils examined were found to contain one or more active cellulose-destroying forms and most of the species isolated were found in two or more soils from widely separated districts. One of the most active forms *(B. imminutus)* was isolated from ten of the sixty-nine soils examined. From the southern California soils studied fifteen new species of cellulose-dissolving bacteria have been isolated and described. In addition to the new species found, seven species previously isolated from other soils have been identified. The distribution of the cellulose-dissolving bacteria found in the southern California soils is shown in Table I.

It is well known that a very rapid destruction of cellulose occurs in many citrus soils of southern California. The question naturally arises whether the rapid destruction of cellulose in these soils is due to the presence of unusually active cellulose-destroying organisms or to favorable conditions which make possible a very rapid multiplication of the cellulose-dissolving organisms present. From the studies made, it is evident that the soils are abundantly supplied with active cellulose-destroying bacteria. Moreover, some of the most active forms appear to have a very wide distribution in the soils of southern California. However, with the possible exception of *B. imminutus* the cellulose-destroying bacteria found in southern California soils, when placed under standard conditions, appear to be no more active agents in the destruction of cellulose than the organisms isolated from the humid regions of the United States. In any explanation of the rapid destruction of cellulose in these soils we must take into consideration the activity of filamentous fungi and possibly the Actinomyces. The cellulose-destroying fungi are unquestionably less numerous and less active in the semi-arid soils of southern California than in the humid soils of the eastern part of the United States. The same is apparently true of the cellulose-destroying species of Actinomyces.

TABLE I

DISTRIBUTION OF CELLULOSE-DISSOLVING BACTERIA IN SOUTHERN CALIFORNIA SOILS

	Arlington	Azusa	Banning	Barstow	Berkeley	Bonita	Chula Vista	Corona	Covina	Davis	Fullerton	Glendora	Highgrove	Highland	Lordsburg	Mentone	Monrovia	Pasadena	Porterville	Redlands	Riverside	San Fernando	Sanger	Santa Paula	Tustin	Uplands	Whittier	Wineville
B. albidus	*																								*			
B. almus	*			*		*												*										
B. conjunctus									*												*							
B. desidiosus									*												*						*	
B. festinus			*								*																*	
B. gilvus		*					*			*																		
B. imminutus		*			*			*			*			*				*	*	*							*	
B. ingis															*							*						
Bact. castigatum			*									*				*												
Bact. idoneum																	*											
Bact. lucrosum					*																							
Bact. paludosum																										*		
Ps. arguta		*				*									*													
Ps. minuscula								*				*					*											
Ps. mira													*															
B. biazoteus (29)	*																											
B. galbus (29)				*						*																		
B. gelidus (29)							*																					
B. subalbus (29)																	*				*				*			
Bact. fimi (42)	*												*															
Bact. flavigenum (28)																								*				
Ps. subcreta (42)																												

The writer's extensive studies of the cultural characteristics of cellulose-destroying organisms has shown that a rapid destruction of cellulose occurs only when the culture medium is thoroughly aerated and contains an abundant supply of available nitrogen. It is also essential that fairly high temperatures be maintained. The thorough cultivation given most citrus soils in southern California insures thorough aeration. The surface soil to which the organic matter is usually added is generally well supplied with available nitrogen. The soil temperature even during the winter months is seldom below that at which a rapid multiplication of the cellulose-dissolving organisms takes place. In view of the above stated conditions, it would seem that the very rapid destruction of cellulose in these soils is probably due more to the very favorable cultural and climatic conditions which make possible the rapid multiplication of the cellulose-dissolving organisms in these soils.

New Species of Cellulose-Dissolving Bacteria

It is obvious that an adequate knowledge of cellulose decomposition in soils must be based upon a clear understanding of the character of the cellulose-dissolving micro-flora of soils. This knowledge can be obtained only by an arrangement of the organisms studied in a logical system of classification such as will make possible a comparative study of the forms described. In the establishment of the points of differentiation upon which separation may be based, there are of course many possible methods of procedure varying according to the points of resemblance which are selected as important.

In working out the description of new species of cellulose-dissolving bacteria, an attempt has been made to bring out the individual characteristics as concisely as possible. Many of the data called for by the card of the Society of American Bacteriologists seem to have little significance in the separation of members of this group. Moreover, in the isolation and classification of this group of organisms it has been found necessary to prepare several new varieties or culture media which are of especial importance in the classification of the cellulose-dissolving organisms, but would probably be of little imporance in the classification of ordinary saprophytic bacteria in soils. So far as we are able to determine none of the cellulose-dissolving organisms isolated have been previously described as saprophytic forms. In view of the above stated conditions and the fact that the power to dissolve cellulose forms a definite basis for the group, we believe that the classification of the cellulose-dissolving organisms can be most satisfactorily accomplished by the employment of only those media which are of especial importance in differentiating the members of this particular group and by using only those characters which remain constant through several sets of cultures.

Bacillus albidus, n. sp.

SOURCE: Soil from Tustin, California.

I. MORPHOLOGY.

1. Vegetative cells: Average dimensions 1 x .004 μ.
2. Endospores: None observed.
3. Flagella: 1 to 3 in number; 3 to 5 μ in length.
4. Staining reactions: Gram negative. Stain readily with the aniline dyes.

II. CULTURAL CHARACTERISTICS.

5. Agar strokes, 5 days.
   Beef Agar: Scant, white, spreading growth.
   Potato agar: Abundant, white to grayish white growth, spreading over the entire slope.
   Peptone starch agar: Moderate, white to gray white growth.
6. *Potato cylinders:* No growth in 30 days.
7. *Gelatin stab:* Scant growth at surface and perceptible growth along the track of the needle; in 5 days. No liquefaction in 30 days.
8. *Beef broth,* 5 days. Not clouded.
9. *Litmus milk:* Reddened in 7 days, neither coagulated nor digested in 30 days.
10. Plate cultures.
    Ammonia cellulose agar, 15 days.
    Form: Colonies at the immediate surface of the medium are round, those located a little beneath the surface are irregularly round.
    Size: 8 to 12 mm.
    Enzymic zone: Clearing all within colony after 15 days. After 30 days the colonies show an enzymic zone of 1 to 2 mm.
    Elevation: Saucer shaped.
    Chromogenesis: Entire colony is vitreous with the exception of a thin, white rim.
    Internal structure: Indeterminate.
    Edge: Entire to undulate.
    Peptone starch agar, 5 days.
    Form: Colonies at the immediate surface are round, those slightly below the surface are irregularly round.
    Size: 2 to 3 mm.
    Enzymic zone: 1 to 1.5 mm.
    Elevation: Slightly convex.
    Chromogenesis: White to light grayish white.
    Internal structure: Coarsely granular; granules often arranged in clumps.
    Edge: Entire to undulate.
    Beef agar, 5 days.
    Form: Round.
    Size: 1 to 1.50 mm.
    Elevation: Convex.
    Consistency: Soft; colonies from 10 to 15 days old become brittle.
    Chromogenesis: By reflected light the colonies are light grayish white. By transmitted light they appear as semi-transparent glistening drops.
    Internal structure: Granular.
    Edge: Entire.

Potato agar, 5 days.
Form: Round.
Size: 2 to 3 mm.
Elevation: Convex.
Consistency: Soft, colonies from 15 to 20 days old become brittle.
Chromogenesis: Semi-transparent white, with pearl-like luster.
Internal structure: Granular.

11. *Filter paper broths*, 15 days. The paper is reduced to a thin, filmy grayish white mass which readily breaks up on slight agitation. The paper is readily attacked in solutions supplied with ammonium sulphate or peptone; but is much slower in solutions containing potassium nitrate or casein as the source of nitrogen.

III. BIOCHEMICAL FEATURES.

12. *Dunham's solution*, 10 days: No ammonia produced; no nitrite produced.
13. *Starch nitrate broth*, 10 days: No ammonia produced; no nitrite produced.
14. *Peptone nitrite solution*, 10 days: No indol produced.
15. *Carbohydrate broths*, 12 days: No gas produced. Per cent of acidity (Fuller's Scale) with: Dextrose, .50; Lactose, .20; Saccharose, .10; Malthose, .10; Glycerine, .10; Mannite, .10; Starch, .10.

Bacillus almus, n. sp.

SOURCE: Soil from Arlington, California; Bonito, California, and Pasadena, California.

I. MORPHOLOGY.

1. Vegetative cells: Average dimensions1.2 x .5 μ.
2. Endospores: None observed.
3. Flagella: 1 to 5 in number; 3 to 4 μ in length.
4. Staining reactions: Gram negative. Stains readily with the aniline dyes.

II. CULTURAL CHARACTERISTICS.

5. Agar strokes, 5 days.
   Beef agar: Scant, white to graylsh white growth. On slopes from 10 to 15 days old the growth becomes yellowish white.
   Potato agar: Moderate, glistening, grayish white growth. After 10 days, the growth becomes yellowish.
   Peptone starch agar: Moderate, glistening, grayish white growth, which becomes yellowish on old slopes.
6. *Potato cylinders:* No growth in 30 days.
7. *Gelatin stab:* Scant growth at surface and along track of the needle, in 5 days. No liquefaction in 30 days.
8. *Beef broth*, 5 days. Lightly clouded.
9. *Litmus milk:* Reddened in 6 days; neither coagulated nor digested in 30 days.
10. Plate cultures.
    Ammonia cellulose agar, 15 days.
    Form: Round.
    Size: 4 to 6 mm. in 15 days; 6 to 8 mm. in 30 days.
    Enzymic zone: 1 to 1.5 mm. in 15 days; in 25 days 3 to 4 mm.
    Elevation: Saucer shaped.

Chromogenesis: Semi-transparent, grayish white after 15 days; older colonies become yellowish white with a narrow grayish white rim.

Internal structure: Colony is made up of fine loosely arranged granules. The rim of the older colonies is composed of large granules compactly arranged.

Edge: Entire.

Peptone cellulose agar, 15 days.

Form: Round or irregularly round.

Size: 5 to 7 mm. in 15 days; in 25 days colonies frequently attain a diameter of 20 mm.

Enzymic zone: 2 mm. in 15 days; 2.5 to 3.5 mm. in 30 days.

Elevation: Saucer shaped.

Chromogenesis: Central portion of colony 2 to 3 mm. in diameter is semi-transparent, grayish white; outer portion of colony is vitreous. The colony is usually surrounded by a narrow white rim.

Internal structure: Central portion of colony is granular; structure of the vitreous portion is indeterminate.

Edge: Entire to undulate.

Peptone starch agar, 5 days.

Form: Irregular. Those colonies at the immediate surface are round or nearly round, but those beneath the surface and the bottom colonies are quite irregular in outline.

Size: 2 to 3 mm.

Enzymic zone: 3 to 4 mm.

Elevation: Flat or very slightly convex.

Chromogenesis: The surface colonies show a small white nucleus, the remainder of the colony grayish white. The imbedded and bottom colonies are grayish to grayish white.

Internal structure: Granular.

Edge: Lacerate.

Beef agar, 5 days.

Form: Round.

Size: Surface colonies 1 to 1.5 mm.; bottom colonies 2 to 3 mm.

Elevation: Convex.

Consistency: Colony is soft during the first 10 days, after which it becomes brittle.

Chromogenesis: By reflected light the colonies are white to light grayish white. By transmitted light they are translucent light, smoky brown.

Structure: Granular.

Edge: Entire.

Potato agar, 5 days.

Form: Round.

Size: Surface colonies, 1 to 2 mm.; bottom colonies, 2 to 3 mm.

Elevation: Pulvinate.

Consistency: Butyrous after 5 days; somewhat viscous after 10 days.

Chromogenesis: Glistening, yellowish to grayish white.

Internal structure: Granular.

Edge: Entire.

11. *Filter paper broths,* 15 days. Paper reduced to a loose, felt-like mass which retains the pure white color of the paper. The structure of the paper has been entirely destroyed, as can be easily demonstrated by the slight agitation of the solution. The decomposition of the paper was less rapid with casein or potassium nitrate as the source of nitrogen than with peptone or ammonium sulphate.

III. BIOCHEMICAL FEATURES.

12. *Dunham's solution,* 10 days: No ammonia produced; no nitrite produced.
13. *Starch nitrate broth,* 10 days: No ammonia produced; no nitrite produced.
14. *Peptone nitrite solution,* 10 days: No indol produced.
15. *Carbohydrate broths,* 12 days: No gas produced. Per cent of acidity (Fuller's Scale) with: Dextrose, 1.30; Lactose, .80; Saccharose, 1.00; Maltose, 1.20; Glycerine, .40; Mannite, .00; Starch, .60.

Bacillus concitatus, n. sp.

SOURCE: Soil from Barstow, California; Covina, California; Riverside, California.

I. MORPHOLOGY.

1. Vegetative cells: Average dimensions, 1.2 x .5 μ.
2. Endospores: None observed.
3. Flagella: 1 to 3 in number; 3 to 4 μ in length.
4. Staining reactions: Gram negative. Stains readily with the aniline dyes.

II. CULTURAL CHARACTERISTICS.

5. Agar strokes, 5 days.
   Beef agar: Abundant, flat, moist, yellowish white.
   Potato agar: Abundant, raised, moist, glistening, grayish white; old cultures become somewhat yellowish white.
   Peptone starch agar: Abundant, raised, frequently somewhat rugose, grayish white.
6. *Potato cylinders:* No growth in 30 days.
7. *Gelatin stab:* Moderate growth at surface and along stab in 5 days; slight napiform liquefaction after 30 days.
8. *Beef broth,* 5 days: Heavily clouded.
9. *Litmus milk:* Reddened in 4 days; no curdling or digestion apparent after 30 days.
10. Plate cultures.
    Ammonia cellulose agar, 15 days.
    Form: Surface colonies are round or irregularly round; bottom colonies spread out into irregular somewhat amoeboid growths.
    Size: Surface colonies are from 1 to 5 mm.; bottom colonies frequently attain a diameter of 15 mm.
    Enzymic zone: Surface colonies, 1 to 1.5 mm.; bottom colonies sometimes show no enzymic zone, but the colony is always more transparent than the surrounding medium, showing that some of the cellulose within the colony has been dissolved.
    Elevation: Flat or slightly depressed.
    Chromogenesis: Many of the colonies are almost pure white, while others show very thin brownish rings.
    Internal structure: Brownish rings coarsely granular; remainder of colony finely granular.
    Edge: Entire.

Peptone cellulose agar, 15 days.

Form: Surface colonies round; bottom colonies irregularly round.

Size: Surface colonies, 1 to 2 mm.; bottom colonies 12 to 15 mm.

Enzymic zone: Surface colonies, 2 to 2.5 mm.; bottom colonies, 1 mm. or less.

Elevation: Flat or very slightly convex.

Chromogenesis: Central portion of colony opaque white; outer portion, semi-transparent grayish white. Brownish rings sometimes apparent.

Internal structure: Central portion of colony coarsely granular, remainder of colony finely granular.

Edge: Usually entire, but some colonies throw out a thin film-like growth beyond the enzymic zone forming ear-like lobes.

Beef agar, 5 days.

Form: Round or irregularly round.

Size: Surface colonies 2 to 3 mm.; bottom colonies frequently spread over a large part of the plate.

Elevation: Decidedly convex.

Consistency: Soft; old colonies become slightly viscous.

Chromogenesis: White or light grayish white; bottom colonies frequently somewhat fluorescent.

Internal structure: Granular.

Edge: Entire to undulate.

Potato agar, 5 days.

Form: Round.

Size: Surface colonies 2 to 3 mm.; bottom colonies may attain a diameter of 10 mm.

Elevation: Distinctly convex; old colonies become somewhat umbilicate.

Consistency: Soft.

Chromogenesis: Glistening grayish white; some colonies show a white nucleus and rim.

Internal structure: Granular; nucleus is more coarsely granular than remainder of colony.

Edge: Entire.

11. *Filter paper broths*, 15 days. The paper is reduced to a disintegrated fibrous mass which retains its pure white color. The destruction takes place at about the same rate with ammonium sulphate, potassium nitrate or peptone as the source of nitrogen. With casein as a source of nitrogen the destruction of the paper is less rapid.

III. BIOCHEMICAL FEATURES.

12. *Dunham's solution*, 10 days. No ammonia produced; no nitrite produced.
13. *Starch nitrate solution*, 10 days. No ammonia produced; nitrite produced.
14. *Peptone nitrite solution*, 10 days. Indol produced.
15. *Carbohydrate broths*, 12 days. No gas produced. Per cent of acidity (Fuller's Scale) with: Dextrose, 1.80; Lactose, .85; Saccharose, 1.30; Maltose, 1.30; Glycerine, .45; Mannite, .00; Starch, 1.35.

Bacillus desiduosus, n. sp.

SOURCE: Soil from Covina, California, and Riverside, California.

I. MORPHOLOGY.

1. Vegetative cells: Average dimensions 1 x .4 μ.
2. Endospores: None observed.
3. Flagella: 1 to 3 in number; 3 to 5 μ in length.
4. Staining reactions: Gram negative. Stains readily with the aniline dyes.

II. CULTURAL CHARACTERISTICS.

5. Agar strokes, 5 days.
   Beef agar: Scant, flat, grayish white, filiform growth.
   Potato agar: Moderate, dry, cream-colored growth.
   Peptone starch agar: Abundant, grayish white growth.
6. *Potato cylinder:* No growth in 30 days.
7. *Gelatin stab:* Moderate grayish white growth at surface and along track of needle, in 5 days; no liquefaction in 30 days.
8. *Beef broth*, 5 days: Lightly clouded.
9. *Litmus milk:* Reddened in 3 days; neither coagulated nor digested in 30 days.
10. Plate cultures.
    Ammonia cellulose agar, 15 days.
    Form: Irregularly round.
    Size: Surface colonies are small, rarely becoming more than 1.5 mm. in diameter; bottom colonies frequently attain a diameter of 12 mm.
    Enzymic zone: 2 to 2.5 mm. in 15 days; 3 to 3.5 mm. in 25 days.
    Elevation: Slightly convex.
    Chromogenesis: Colony is gray white with the exception of a small white nucleus and a narrow white rim.
    Structure: Granular.
    Edge: Erose.
    Peptone cellulose agar, 15 days.
    Form: Irregularly round.
    Size: Surface colonies 1 to 2 mm.; bottom colonies may attain a diameter of 25 mm.
    Enzymic zone: Surface colonies 1 to 2 mm.; bottom colonies frequently show no enzymic zone until after 20 days.
    Elevation: Slightly convex.
    Chromogenesis: Surface colonies are semi-transparent, yellowish white. After 20 days' growth the surface and imbedded colonies become quite yellowish; bottom colonies remain grayish white.
    Internal structure: Granular.
    Edge: Lobate.
    Peptone starch agar, 5 days.
    Form: Surface and bottom colonies are round or irregularly round; imbedded colonies are flaky.
    Size: .1.5 to 2.5 mm.
    Enzymic zone: 1 to 1.5 mm. in 5 days; 2 to 2.5 mm. in 10 days.
    Elevation: Flat.
    Chromogenesis: Grayish white; some colonies show a small white nucleus.

Internal structure: Coarsely granular. The granules are frequently formed into large granular clumps.
Edge: Entire or undulate.

Beef Agar, 5 days.
Form: Surface colonies round; bottom colonies spread out into fern-like growths.
Size: Surface colonies 1 to 1.5 mm.; bottom colonies 12 to 15 mm.
Elevation: Slightly convex.
Consistency: Soft; old colonies are somewhat viscous.
Chromogenesis: By reflected light the colonies are grayish white; by transmitted light they appear as glistening semi-transparent drops.
Structure: Granular.
Edge: Entire.

Potato agar, 5 days.
Form: Round.
Size: 1 to 1.5 mm.
Elevation: Convex.
Consistency: Very soft; colony can be caused to spread over the medium by shaking the plate.
Chromogenesis: By reflected light the colonies are grayish white. By transmitted light they appear as glistening semi-transparent drops.
Structure: Granular.
Edge: Entire.

11. *Filter paper broths*, 15 days. Paper is reduced to a finely divided gray white mass which readily separates into minute fibrous particles on slight agitation. The paper is decomposed rapidly with ammonium sulphate, potassium nitrate, peptone or casein as the source of nitrogen.

III. BIOCHEMICAL FEATURES.

12. *Dunham's solution*, 10 days. No ammonia formed; nitrite formed.
13. *Starch nitrate solution*, 10 days. No ammonia formed; nitrite formed.
14. *Peptone nitrite solution*, 10 days. Indol produced.
15. *Carbohydrate broths*, 12 days. No gas produced. Per cent of gas (Fuller's Scale) with: Dextrose, .80; Lactose, .10; Saccharose, .00; Maltose, .60; Glycerine, .00; Mannite, .00; Starch, .20.

Bacillus festinus, n. sp.

SOURCE: Soil from Banning, California; Fullerton, California; Whittier, California.

I. MORPHOLOGY.

1. Vegetative cells: Average dimensions 2 x .6 μ.
2. Endospores: Form, elliptical; size, average dimensions .8 x .5 μ; germination, equatorial; rod, swollen.
3. Flagella: 1 to 3 in number; 4 to 6 μ in length.
4. Staining reactions: Gram negative. Stains readily with the aniline dyes.

II. CULTURAL CHARACTERISTICS.

5. Agar strokes, 5 days.
Beef agar: Scant, flat, grayish white, spreading growth.

Potato agar: Abundant, grayish white, flat growth, usually spreading over the entire slope.

Peptone starch agar: Moderate, grayish white after 5 days, but in cultures from 6 to 10 days old the growth becomes a rich orange. The pigment diffuses through the medium very slowly.

6. *Potato cylinders:* No growth in 30 days.
7. *Gelatin stab:* Scant growth at surface and along track of the needle in 10 days. No liquefaction in 30 days.
8. *Beef broth:* Not clouded in 5 days.
9. *Litmus milk:* Reddened in 3 days; coagulated and digested in 25 days.
10. Plate cultures.

Ammonia cellulose agar, 15 days.

Form: Round.

Size: 10 to 12 mm. The colonies continue to grow after 15 days, and when kept in a moist chamber for 30 days the colonies frequently attain a diameter of 25 mm.

Enzymic zone: In young colonies the clearing is all within the colony; after 30 days the enzymic zone is frequently 2 to 3 mm.

Elevation: Saucer-shaped.

Chromogenesis: The central portion of the colony, usually 6 to 10 mm. in diameter, is semi-transparent grayish white. The remainder is vitreous with the exception of a thin white rim.

Internal structure: The central portion of the colony is made up of loosely arranged, coarse granules. The structure of the vitreous zone is indeterminate.

Edge: Entire.

Peptone cellulose agar, 15 days.

Form: Round.

Size: 5 to 6 mm. in 15 days; 10 to 12 mm. in 30 days.

Enzymic zone: 2 to 3 mm.

Elevation: Saucer-shaped.

Chromogenesis: Central portion of colony is transparent or semi-transparent grayish white. Outer portion of colony is semi-transparent yellowish white. Colony is usually surrounded by a thin yellowish white rim.

Internal structure: The colony is composed of fine granules loosely arranged.

Edge: Entire.

Peptone starch agar, 5 days.

Form: Surface colonies, round; imbedded and bottom colonies irregularly round.

Size: 15 to 25 mm.

Enzymic zone: 2 to 3 mm. in 5 days; 3.5 to 4 mm. in 10 days.

Elevation: Flat or very slightly convex.

Chromogenesis: Central portion of colony is a rich orange, outer portion grayish to yellowish white.

Internal structure: Consists of large granules frequently formed into clumps.

Edge: Entire to undulate.

Beef Agar, 5 days.

Form: Round.

Size: Surface colonies 1 mm. or less; bottom colonies 3 to 4 mm.

Elevation: Slightly convex.
Consistency: Butyrous, old colonies become brittle.
Chromogeniesis: White nucleus, remainder semi-transparent, glistening, grayish white.
Internal structure: Finely granular with exception of nucleus which is made up of granular clumps.

Potato agar, 5 days.
Form: Round.
Size: Surface colonies 2 to 3 mm.; bottom colonies 4 to 5 mm.
Elevation: Convex; old colonies frequently become somewhat umbilicate.
Consistency: Butyrous.
Chromogenesis: Grayish to yellowish white. Sometimes shows brownish rings.
Internal structure: Finely granular.
Edge: Entire.

11. *Filter paper broths,* 15 days. Paper is very completely disintegrated into a grayish white felt-like mass, which readily separates into minute fibrous particles on slight agitation. The paper undergoes rapid decomposition when the nutrient solution contains inorganic nitrogen in the form of ammonium sulphate or potassium nitrate, and also when organic nitrogen is added in the form of peptone or casein.

III. BIOCHEMICAL FEATURES.

12. *Dunham's solution,* 10 days. No ammonia produced; no nitrite produced.
13. *Starch nitrate solution,* 10 days. No ammonia produced; nitrite produced.
14. *Peptone nitrite solution,* 10 days. Indol produced.
15. *Carbohydrate broths,* 12 days. No gas produced. Per cent of acidity (Fuller's Scale) with: Dextrose, .50; Lactose, .40; Saccharose, .00; Maltose, .65; Glycerine, .05; Mannite, .00; Starch, .60.

Bacillus gilvus, n. sp.

SOURCE: Soil from Azusa, California; Chula Vista, California; Davis, California; Porterville, California; and Riverside, California.

I. MORPHOLOGY.

1. Vegetative cells: Average dimensions 1.5 x .5 μ.
2. Endospores: None observed.
3. Flagella: 1 to 4 in number; 4 to 6 μ in length.
4. Staining reactions: Gram negative. Stains readily with the aniline dyes.

II. CULTURAL CHARACTERISTICS.

5. Agar strokes, 5 days.
Beef agar: Scant, yellowish white, filiform growth.
Potato agar: Abundant, canary yelfow, growth spreading over a large part of the slope.
Peptone starch agar: Abundant, grayish white, glistening growth which becomes somewhat yellowish after 10 days.
6. *Potato cylinders:* Abundant canary yellow in 5 days.
7. *Gelatin stab:* Moderate yellowish white growth at surface and along track of needle in 10 days; no liquefaction in 30 days.

8. *Beef broth,* 5 days: Slightly clouded.
9. *Litmus milk:* Reddened in 6 days; neither coagulated nor digested in 30 days.
10. Plate cultures.

Ammonia cellulose agar, 15 days.
Form: Round to irregularly round.
Size: 2 to 3 mm.
Enzymic zone: Entire colony semi-transparent; enzymic zone not more than 1 mm.
Elevation: Flat or slightly depressed.
Chromogenesis: Semi-transparent, grayish white, usually showing a small white nucleus.
Internal structure: Granular.
Edge: Entire to undulate.

Peptone cellulose agar, 15 days.
Form: Round.
Size: 2 to 4 mm.
Enzymic zone: 1.5 to 2 mm. in 15 days; 3 to 4 mm. in 25 days.
Elevation: Slightly concave.
Chromogenesis: Grayish white, frequently showing a small white nucleus, usually forms a thin grayish white semi-transparent rim beyond the enzymic zone.
Internal structure: Granular.
Edge: Entire.

Peptone starch agar, 5 days.
Form: Round to irregularly round.
Size: 2 to 3 mm.
Enzymic zone: 1 to 1.5 mm.
Elevation: Slightly convex.
Consistency: Soft, becoming brittle after 10 days.
Chromogenesis: Grayish to yellowish white. After 10 days the colonies become quite yellowish.
Internal structure: Granular.
Edge: Entire to undulate.

Beef Agar, 5 days.
Form: Round.
Size: Surface colonies 1 to 2 mm.; bottom colonies 3 to 3.5 mm.
Elevation: Convex.
Consistency: Soft.
Chromogenesis: After 3 days the colonies are grayish to yellowish white; the yellow color increases with the age of the colony and after 10 days they are distinctly yellow.
Internal structure: Coarsely granular. The granules are frequently formed into clumps.
Edge: Entire.

Potato agar, 5 days.
Form: Round.
Size: 2 to 3 mm.
Elevation: Convex.
Consistency: Butyrous.
Chromogenesis: Canary yellow; some colonies show brownish rings.
Internal structure: Granular.
Edge: Entire.

11. *Filter paper broths,* 15 days. The paper is reduced to a thin white filmy mass which breaks up into minute particles on slight agitation. The decomposition of the paper proceeds rapidly with ammonium sulphate, potassium nitrate, peptone or casein as the source of nitrogen.

III. BIOCHEMICAL FEATURES.

12. *Dunham's solution,* 10 days. Ammonia formed; nitrite formed.
13. *Starch nitrate solution,* 10 days. No ammonia formed; nitrite formed.
14. *Peptone nitrite solution,* 10 days. Indol formed.
15. *Carbohydrate broths,* 12 days. No gas produced. Per cent of acidity (Fuller's Scale) with: Dextrose, 1.20; Lactose, .75; Saccharose, .80; Maltose, 1.00; Glycerine, .40; Mannite, .00; Starch, 1.00.

Bacillus imminutus, n. sp.

SOURCE: Soil from Highland, California; Berkeley, California; Corona, California; Redlands, California; Whittier, California; Santa Paula, California; Pasadena, California; Azusa, California; Fullerton, California; Porterville, California.

I. MORPHOLOGY.

1. Vegetative cells: Average dimensions 1.5 x .2 μ. The vegetative cells pass quickly into involution forms which frequently attain a length of from 6 to 8 μ without increasing in thickness. The involution forms are commonly curved cells, frequently more or less fusiform.
2. Endospores: Form, round; average size, .5 μ; germination, polar. Rod is swollen during germination, giving the cell a drumstick appearance. On cellulose agar the spores appear in from 4 to 6 days.
3. Flagella: 1 to 5 in number; 3 to 5 μ in length.
4. Staining reactions: Gram negative. Stains readily with the aniline dyes.

II. CULTURAL CHARACTERISTICS.

5. Agar strokes, 5 days.
   Beef agar: No growth.
   Potato agar: No growth.
   Peptone starch agar: No growth.
6. *Potato cylinders:* No growth in 30 days.
7. *Gelatine stab:* No growth in 30 days.
8. *Beef broth,* 5 days: No growth.
9. *Litmus milk:* No growth in 30 days.
10. Plate cultures.
    Ammonia cellulose agar, 15 days.
    Form: Round.
    Size: The size of the colonies is quite variable; after 15 days the diameter is usually between 12 and 15 mm. The colony continues to increase in size as long as the medium remains moist, and where plates can be kept free from molds a single colony may eventually cover the entire plate. The round form of the colony is maintained as long as the growth is unobstructed.

Enzymic zone: The entire colony is transparent. The enzyme does not clear the cellulose beyond the development of the colony.

Elevation: Young colonies are saucer-shaped. As the colony spreads the depression is less apparent.

Chromogenesis: Vitreous. Some colonies show a very narrow white rim. Old colonies frequently become a light transparent yellow.

Internal structure: Granular.

Edge: Entire.

Peptone cellulose agar, 15 days.

Form: Round.

Size: 10 to 12 mm. in 15 days; colonies continue to grow as long as the medium is kept moist. When the plate contains only a very few colonies the diameter may be 50 mm. or more in 30 days.

Enzymic zone: The entire colony is transparent with the exception of a very narrow white rim. The enzyme does not spread beyond the development of the colony.

Elevation: The young colonies are distinctly concave. As the colony becomes older the depression is less apparent.

Chromogenesis: Vitreous. Some colonies show a very narrow white rim. Old colonies frequently become a light trasparent yellow.

Internal structure: Indeterminate with the exception of the narrow white rim which is granular.

Edge: Entire.

Peptone starch agar: No colonies produced in 10 days.

Beef agar: No colonies produced in 10 days.

Potato agar: No colonies produced in 10 days.

11. *Filter paper broths,* 15 days. The paper is reduced to a very thin yellowish filmy mass, which disintegrates on very slight agitation. The paper is destroyed at about the same rate with ammonium sulphate, potassium nitrate or peptone as the source of nitrogen. A slower destruction of the paper occurs when nitrogen is supplied in the form of casein.

III. BIOCHEMICAL FEATURES.

12. *Dunham's solution,* 10 days. No ammonia produced; no nitrite produced.
13. *Starch nitrate solution,* 10 days. No ammonia produced; no nitrite produced.
14. *Peptone nitrite solution,* 10 days. No indol produced.
15. *Carbohydrate broths,* 12 days. No gas produced. Per cent of acidity (Fuller's Scale) with: Dextrose, 0.00; Lactose, 0.00; Saccharose, 0.00; Maltose, 0.00; Glycerine, 0.00; Mannite, 0.00; Starch, 0.00.

Bacillus iugis, n. sp.

SOURCE: Soil from Lordsburg, California; Redlands, California; and San Fernando, California.

I. MORPHOLOGY.

1. Vegetative cells: Average dimensions 1.4 x .4 μ.
2. Endospores: None observed.

3. Flagella: 1 to 3 in number; 3 to 4 μ in length.
4. Staining reactions: Gram negative. Stains readily with the aniline dyes.

II. CULTURAL CHARACTERISTICS.

5. Agar strokes, 5 days.
   Beef agar: Scant, grayish white, filiform growth.
   Potato agar: Abundant, glistening, grayish white, filiform growth.
   Peptone starch agar: Moderate, grayish white, filiform growth.
6. *Potato cylinders,* 30 days: Scant, glistening, colorless growth when very heavily inoculated. Light inoculation produces no growth.
7. *Gelatin stab:* Moderate growth at surface and along track of needle in 5 days; napiform liquefaction in 30 days.
8. *Beef broth,* 5 days: Heavily clouded.
9. *Litmus milk:* Reddened in 5 days; neither coagulated nor digested in 30 days.
10. Plate cultures.
    Ammonia cellulose agar, 15 days.
    Form: Round.
    Size: 1.5 to 2.5 mm. in 15 days; 3 to 3.5 mm. in 25 days.
    Enzymic zone: Clearing sometimes all within colony after 15 days. After 20 days all colonies show an enzymic zone of 1 mm. or more.
    Elevation: Flat.
    Chromogenesis: Semi-transparent, light grayish white; sometimes contoured by light whitish lines.
    Internal structure: Granular.
    Edge: Entire.
    Peptone cellulose agar, 15 days.
    Form: Irregularly round.
    Size: 5 to 8 mm. in 15 days; no increase in size after 15 days.
    Enzymic zone: 2 to 3 mm. The zone continues to increase in width up to 30 days, in which time it is frequently 5 mm.
    Elevation: Slightly convex.
    Chromogenesis: Central portion of colony is white; the outer portion gray-white; sometimes forms a white nucleus and rim.
    Internal structure: Central portion of colony coarsely granular, outer portion finely granular.
    Edge: Undulate to lobate.
    Peptone starch agar, 5 days.
    Form: Irregularly round.
    Size: 1.5 to 2 mm. in 15 days; 2.5 mm. in 25 days.
    Enzymic zone: 1 mm. or less.
    Elevation: Capitate. (The colonies on starch agar are raised in a characteristic jelly-like mass.)
    Consistency: Gelatinous.
    Chromogenesis: Grayish white.
    Internal structure: Fine granules loosely arranged.
    Edge: Lancelate.
    Beef agar, 5 days.
    Form: Surface colonies round; imbedded colonies, lenticular.
    Size: 1.5 to 2 mm.
    Elevation: Convex.

Consistency: Soft; old colonies become somewhat gelatinous.
Chromogenesis: Small white nucleus, remainder semi-transparent grayish white.
Internal structure: Granular.
Edge: Entire.

Potato agar, 5 days.
Form: Surface colonies, round; bottom colonies, irregularly round.
Size: Surface colonies 1 to 1.5 mm.; bottom colonies 2.5 to 4 mm.
Elevation: Convex.
Consistency: Soft.
Chromogenesis: Grayish white, with a pearl-like luster.
Internal structure: Granular.
Edge: Entire.

11. *Filter paper broths*, 15 days. The paper retains something of its original structure; but shows many ragged holes where the fibers have been dissolved away. Very slight agitation is sufficient to disintegrate the paper mass completely. The decomposition takes place at about the same rate with ammonium sulphate or peptone as the source of nitrogen. The decomposition was much slower when casein or potassium nitrate was used.

III. BIOCHEMICAL FEATURES.

12. *Dunham's solution*, 10 days. Ammonia produced; nitrite produced.
13. *Starch nitrate solution*, 10 days. No ammonia produced; nitrite produced.
14. *Peptone nitrite solution*, 10 days. No indol produced.
15. *Carbohydrate broths*, 12 days. No gas produced. Per cent of acidity (Fuller's Scale) with: Dextrose, .80; Lactose, 1.10; Saccharose, 1.60; Maltose, 1.55; Glycerine, .45; Mannite, .20; Starch, 1.50.

Bacterium castigatum, n. sp.

SOURCE: Soil from Banning, California; Glendora, California; and Wineville, California.

I. MORPHOLOGY.

1. Vegetative cells: Average dimensions 1.2 x .4 μ.
2. Endospores: None observed.
3. Staining reactions: Gram negative. Stains readily with the aniline dyes.

II. CULTURAL CHARACTERISTICS.

4. Agar strokes, 5 days.
Beef agar: Abundant, moist, glistening, grayish white growth.
Potato agar: Abundant, glistening, grayish white; becomes yellowish white after 10 days.
Peptone starch agar: Abundant, raised, somewhat rugose.
5. *Potato cylinders*, 30 days: No growth.
6. *Gelatin stab:* Moderate growth at surface and along track of needle in 6 days; no liquefaction after 30 days.
7. *Beef broth*, 5 days: Lightly clouded.
8. *Litmus milk:* Reddened in 3 days; neither coagulated nor digested in 30 days.

9. Plate cultures.

Ammonia cellulose agar, 15 days.

Form: Irregularly round.
Size: 1 to 1.5 mm.
Enzymic zone: 1 to 1.5 mm.; in 30 days the enzymic zone may attain a diameter of 2.5 mm.
Elevation: Slightly convex.
Chromogenesis: Opaque white or light grayish white.
Internal structure: Granular.
Edge: Undulate.

Peptone cellulose agar, 15 days.

Form: Irregularly round.
Size: 1 to 1.5 mm.
Enzymic zone: .5 to 1 mm.; in 30 days the enzymic zone may reach a diameter of 2 mm.
Elevation: Slightly convex.
Chromogenesis: White nucleus and rim, remainder of colony grayish white.
Internal structure: Nucleus and rim made up of coarse compact granules, remainder of colony finely granular.
Edge: Undulate.

Peptone starch agar, 5 days.

Form: Irregularly round.
Size: 7 to 10 mm.
Enzymic zone: 1 to 1.5 mm. in 5 days; 2.5 to 3 mm. in 10 days.
Elevation: Flat or slightly convex.
Consistency: Firm.
Chromogenesis: Grayish white cottony-like colony in 5 days; in 10 days colonies become distinctly grayish.
Internal structure: Coarsely granular.
Edge: Lancelate.

Beef agar, 5 days.

Form: Round.
Size: Surface colonies 1 to 1.5 mm.; bottom colonies 2 to 3 mm.
Elevation: Slightly convex.
Consistency: After 5 days colonies are soft; after 10 days, brittle.
Chromogenesis: Very small white nucleus, remainder of colony grayish white. Surface colonies exhibit a pearl-like luster.
Internal structure: Granular.
Edge: Entire.

Potato agar, 5 days.

Form: Surface colonies round; bottom colonies irregularly round.
Size: Surface colonies 1 to 2 mm.; bottom colonies 2 to 3 mm.
Elevation: Convex.
Consistency: After 5 days colonies are soft; after 10 days, butyrous.
Chromogenesis: Light grayish white, semi-transparent colonies with a pearl-like luster.
Internal structure: Made up of fine granules, loosely arranged.
Edge: Entire.

10. *Filter paper broths,* 15 days. Paper very completely disintegrated and reduced to a pulp-like mass which settles to the bottom of the flask. The paper is vigorously attacked in solutions containing ammonium sulphate, potassium nitrate, or peptone as the source of nitrogen. Casein appeared to be less favorable for the rapid development of this organism.

III. BIOCHEMICAL FEATURES.

11. *Dunham's solution,* 10 days. No ammonia formed; nitrite formed.
12. *Starch nitrate broth,* 10 days. No ammonia formed; no nitrite formed.
13. *Peptone nitrite broth,* 10 days. No indol produced.
14. *Carbohydrate broths.* No gas produced. Per cent of acidity (Fuller's Scale) with: Dextrose, 1.50; Lactose, 1.10; Saccharose, 1.00; Maltose, 1.45; Glycerine, .55; Mannite, .00; Starch, 1.40.

Bacterium idoneum, n. sp.

SOURCE: Soil from Mentone, California; and Whittier, California.

I. MORPHOLOGY.

1. Vegetative cells: Average dimensions 1.5 to .5 μ.
2. Endospores: None observed.
3. Staining reactions: Gram negative. Stains readily with the aniline dyes.

II. CULTURAL CHARACTERISTICS.

4. Agar strokes, 5 days.
   Beef agar: Scant, yellowish white, glistening, filiform growth; in 10 days growth becomes distinctly yellowish.
   Potato agar: Abundant, moist, glistening, faint yellowish to glistening white; becomes distinctly yellowish in 10 days.
   Peptone starch agar: Moderate, flat, white, filiform growth; becomes faintly yellowish in 10 days.
5. *Potato cylinders:* Abundant, moist, glistening, grayish white growth in 15 days.
6. *Gelatin stab:* Moderate, yellowish growth at surface and along track of needle in 10 days. Slight napiform liquefaction after 30 days.
7. *Beef broth,* 5 days: Turbid
8. *Litmus milk:* Reddened in 3 days; neither coagulated nor digested in 30 days.
9. Plate cultures.
   Ammonia cellulose agar, 15 days.
   Form: Irregularly round.
   Size: 1 to 1.5 mm.
   Enzymic zone: 1 mm. or less after 15 days; after 30 days the enzymic zone has attained a diameter of 2 to 3 mm.
   Elevation: Flat.
   Chromogenesis: Opaque white or light grayish white.
   Internal structure: The colony is made up of rather coarse granules compactly arranged.
   Edge: Lobate.
   Peptone cellulose agar, 15 days.
   Form: Irregularly round.
   Size: 1 to 1.5 mm.; maximum development is reached in 15 days.
   Enzymic zone: .5 to 1.0 mm. in 15 days; 1.5 to 2 mm. after 30 days.
   Elevation: Flat.

Chromogenesis: Opaque white to light grayish white.
Internal structure: Coarse granules, compactly arranged.
Edge: Lobate.

Peptone starch agar, 5 days.
Form: Irregularly round.
Size: 1 to 2 mm.
Enzymic zone: 1 to 1.5 mm. in 5 days; 2 to 2.5 mm. in 10 days.
Elevation: Convex; frequently somewhat pulvinate.
Consistency: After 5 days the colonies are soft; older colonies become somewhat viscous.
Internal structure: Granular; granules frequently arranged in clumps.
Edge: Lobate.

Beef agar, 5 days.
Form: Round.
Size: Surface colonies 1 to 1.5 mm.; bottom colonies 2 to 3 mm.
Elevation: Convex.
Consistency: Soft; becomes brittle after 10 days.
Chromogenesis: Grayish white pearl-like luster. By transmitted light the colonies appear as semi-transparent glistening drops.
Internal structure: Granular.
Edge: Entire.

Potato agar, 5 days.
Form: Surface colonies, round; imbedded and bottom colonies, irregularly round.
Size: 2 to 3 mm.
Elevation: Pulvinate.
Consistency: After 5 days colonies are soft; after 10 days, butyrous or brittle.
Chromogenesis: Reflected light, yellowish to grayish white; transmitted light, semi-transparent glistening drops.
Internal structure: Coarsely granular.
Edge: Entire.

10. *Filter paper broths,* 15 days. Paper is reduced to a thin limp sheet which falls apart on slight agitation. Solutions containing ammonium sulphate, potassium nitrate and peptone as the source of nitrogen show a rapid decomposition of the paper. Solutions containing casein showed only a slight decomposition of the paper even after 30 days' incubation.

III. BIOCHEMICAL FEATURES.

11. *Dunham's solution,* 10 days. No ammonia formed; nitrite formed.
12. *Starch nitrate broth,* 10 days. No ammonia produced; nitrite produced.
13. *Peptone nitrite solution,* 10 days. No indol produced.
14. *Carbohydrate broths,* 12 days. No gas produced. Per cent of acidity (Fuller's Scale) with: Dextrose, 1.60; Lactose, 1.20; Maltose, 1.40; Mannite, .00; Saccharose, 1.30; Glycerine, .70; Starch, 1.40.

Bacterium lucrosum, n. sp.

SOURCE: Soil from Redlands, California; and Upland, California.

I. MORPHOLOGY.

1. Vegetative cells: Average dimensions 1.3 x .4 μ.
2. Endospores: None observed.

3. Staining reactions: Gram negative. Stains readily with the aniline dyes.

II. CULTURAL CHARACTERISTICS.

4. Agar strokes, 5 days.

Beef agar: Moderate, flat, grayish white; old cultures become somewhat irridescent.

Potato agar: Moderate, dirty yellowish white in 5 days; becomes more yellowish with age.

Peptone starch agar: Abundant, moist, grayish white in 5 days; becomes faintly yellowish in 10 days.

5. *Potato cylinder,* 30 days: No growth.
6. *Gelatin stab:* No growth after 30 days.
7. *Beef broth,* 5 days: Heavily clouded.
8. *Litmus milk:* No change in milk in 30 days.
9. Plate cultures.

Ammonia cellulose agar, 15 days.

Form: Irregularly round.

Size: 15 to 20 mm.; in 30 days the colonies frequently reach a diameter of 25 to 30 mm.

Enzymic zone: When there are only a few colonies on the plate, permitting rapid spreading, the clearing is all within the colony until after 30 days, when an enzymic zone usually develops. On crowded plates the colonies always show an enzymic zone of 1 mm. or more.

Elevation: Slightly concave.

Chromogenesis: Central portion of colony, usually 6 to 19 mm. in diameter, is grayish white; outer portion of colony is vitreous. The vitreous zone is usually surrounded by a thin white rim.

Internal structure: Colony is made up of medium-sized, loosely arranged granules.

Edge: Undulate.

Peptone cellulose agar, 15 days.

Form: Round.

Size: 2 to 3 mm. in 15 days; 3 to 4 mm. in 25 days.

Enzymic zone: 1 to 1.5 mm. in 15 days; 2 to 3 mm. in 25 days.

Elevation: Flat.

Chromogenesis: Nucleus and rim are white, remainder of colony semi-transparent grayish white.

Internal structure: Granular.

Edge: Entire.

Peptone starch agar, 5 days.

Form: Irregularly round.

Size: 3 to 4 mm.

Enzymic zone: .5 to 1 mm. in 5 days; 2 to 3 mm. in 10 days.

Elevation: Convex.

Consistency: Soft; after 10 days colonies become brittle.

Chromogenesis: Central portion of colony semi-transparent, glistening white; outer portion vitreous.

Internal structure: Granular.

Edge: Undulate.

Beef agar, 5 days.

Form: Surface colonies, round; imbedded colonies, lenticular; bottom colonies, irregularly round.

Size: 1 to 1.5 mm.

Elevation: Slightly convex.

Consistency: Soft; in 10 days growth becomes somewhat gelatinous.

Chromogenesis: Very small white nucleus; remainder of colony semi-transparent grayish white.

Internal structure: Granular.

Edge: Entire.

Potato agar, 5 days.

Form: Surface colonies, round; bottom and imbedded colonies, irregularly round.

Size: 1.5 to 2 mm.

Elevation: Convex.

Consistency: Butyrous after 5 days; somewhat gelatinous after 10 days.

Chromogenesis: Yellowish to grayish white; after 10 days colonies become quite yellowish.

Internal structure: Coarsely granular. Some colonies are grumose.

Edge: Entire.

10. *Filter paper broths*, 15 days. Paper is reduced to pulpy grayish white mass consisting of very short fibers which separate on slight agitation. The paper is decomposed rapidly in the ammonium sulphate and peptone broths, but more slowly in the broths containing casein or potassium nitrate.

III. BIOCHEMICAL CHARACTERISTICS.

11. *Dunham's solution*, 10 days. No ammonia produced; nitrite produced.
12. *Starch nitrate solution*, 10 days. No ammonia produced; no nitrite produced.
13. *Peptone nitrite solution*, 10 days. No indol produced.
14. *Carbohydrate broths*. No gas produced. Per cent of acidity (Fuller's Scale) with: Dextrose, .20; Lactose, .10; Saccharose, .00; Maltose, .15; Glycerine, .00; Mannite, .05; Starch, .15.

Bacterium paludosum, n. sp.

SOURCE: Soil from Berkeley, California; Whittier, California.

I. MORPHOLOGY.

1. Vegetative cells: Average dimensions 1.5 x .4 μ.
2. Endospores: Form, elliptical; size, 1.2 x .6 μ; germination, equatorial; rod, swollen. Abundantly produced on potato agar cultures 3 or 4 days old.
3. Staining reactions: Gram negative. Stains readily with the aniline dyes.

II. CULTURAL CHARACTERISTICS.

4. Agar strokes, 5 days.

Beef agar: Moderate, flat, grayish white growth.

Potato agar: Abundant, moist, glistening, grayish white growth.

Peptone starch agar: Moderate, flat, grayish white growth.

5. *Potato cylinder:* Very scant, glistening, colorless growth sometimes occurs on cylinders held in a moist chamber for 30 days, but ordinarily no growth is secured.
6. *Gelatin stab:* Moderate growth at surface and along track of needle in 6 days. After 30 days napiform liquefaction is observed.
7. *Beef broth,* 5 days: Lightly clouded.
8. *Litmus milk:* Reddened in 5 days; neither coagulated nor digested in 30 days.
9. Plate cultures.

Ammonia cellulose agar, 15 days.

Form: Surface colonies, round or irregularly round; bottom colonies frequently develop into fern-like growths.
Size: Surface colonies, 2 to 3 mm.; bottom colonies frequently attain a diameter of 8 to 10 mm.
Enzymic zone: 1 to 3 mm. in 15 days; 3 to 3.5 mm. in 25 days.
Elevation: Slightly convex.
Chromogenesis: Surface colonies show a small white nucleus; remainder of colony, gray-white; bottom colonies are fluorescent.
Internal structure: Coarsely granular.
Edge: Entire to undulate.

Peptone cellulose agar, 15 days.

Form: Irregularly round.
Size: Surface colonies 1.5 to 2.5 mm.; bottom colonies 3 to 5 mm.
Enzymic zone: 1.5 to 2 mm. in 15 days; 2.5 to 3 mm. in 30 days.
Elevation: Convex.
Chromogenesis: White to grayish white. Colonies sometimes show a white nucleus and rim.
Internal structure: Coarsely granular.
Edge: Lacerate.

Peptone starch agar, 5 days.

Form: Irregular; imbedded colonies frequently throw out spine-like growths.
Size: 1.5 to 2 mm.
Enzymic zone: 1.5 to 2 mm. in 5 days; 2.5 to 3.5 mm. in 10 days.
Elevation: Flat.
Chromogenesis: White to light grayish white in 5 days; in 10 days the colonies become dark gray.
Internal structure: Densely granular.
Edge: Lacerate.

Beef agar, 5 days.

Form: Surface colonies round; bottom colonies spread out into irregular growths.
Size: Surface colonies 1.5 to 2 mm.; bottom colonies 10 to 12 mm.
Consistency: Very soft in 5 days; brittle in 10 days.
Chromogenesis: Semi-transparent, glistening, gray-white; frequently form a small white nucleus, and many colonies are more or less concentric in structure. At an angle of 45° the colonies are fluorescent.
Internal structure: Granular.
Edge: Entire to undulate.

Potato agar, 5 days.

Form: Round.

Size: 2 to 3 mm.; bottom colonies are no larger than the surface colonies.

Elevation: Decidedly convex; in 10 days colonies frequently become somewhat unbilicate.

Consistency: Butyrous.

Chromogenesis: Semi-transparent, glistening, light grayish white to almost vitreous. Many colonies exhibit a pearl-like luster.

Internal structure: Finely granular.

Edge: Entire.

10. *Filter paper broths*, 15 days. Paper is reduced to a white pulp-like mass made up of very short disintegrated fibers which become distributed through the solution on slight agitation. The paper is decomposed very rapidly with ammonium sulphate, potassium nitrate, and peptone as the source of nitrogen. The decomposition takes place more slowly when casein is added as the source of nitrogen.

III. BIOCHEMICAL FEATURES.

11. *Dunham's solution*, 10 days. No ammonia produced; nitrite produced.
12. *Starch nitrate solution*, 10 days. No ammonia produced; no nitrite produced.
13. *Peptone nitrite solution*, 10 days. Indol produced.
14. *Carbohydrate broths*, 12 days. No gas produced. Per cent of acidity (Fuller's Scale) with: Dextrose, 1.10; Lactose, .80; Saccharose, 1.00; Maltose, 1.20; Glycerine, .40; Mannite, .05; Starch, 1.20.

Pseudomonas arguta, n. sp.

SOURCE: Soil from Azusa, California; and Whittier, California.

I. MORPHOLOGY.

1. Vegetative cells: Average dimensions .8 x .3 μ.
2. Endospores: None observed.
3. Flagella: 1 to 2 in number; 6 to 8 μ in length.
4. Staining reactions: Gram negative. Stains readily with the aniline dyes.

II. CULTURAL CHARACTERISTICS.

5. Agar strokes, 5 days.
   Beef agar: Scant, grayish white, filiform growth.
   Potato agar: Moderate, yellowish, glistening white.
   Peptone starch agar: Scant, white to grayish white.
6. *Potato cylinders*, 30 days. No growth.
7. *Gelatin stab:* Moderate yellowish growth at surface and along the track of needle in 10 days; no liquefaction in 30 days.
8. *Beef broth*, 5 days: Clouded.
9. *Litmus milk:* Reddened in 4 days; neither coagulated nor digested in 30 days.
10. Plate cultures.
    Ammonia cellulose agar, 15 days.
    Form: Round.
    Size: Surface colonies, 1 to 2 mm.; bottom colonies, 3 to 4 mm.
    Enzymic zone: 1 mm. or less in 15 days; in 30 days the zone frequently becomes 2 or 3 mm.

Elevation: Slightly convex.
Chromogenesis: White nucleus and rim; remainder semi-transparent grayish white.
Structure: Grumose.
Edge: Entire.

Peptone cellulose agar, 15 days.
Form: Round.
Size: 8 to 12 mm. in 15 days; in 30 days the colonies frequently attain a diameter of 20 mm.
Enzymic zone: 1 to 2 mm.
Elevation: Slightly convex.
Chromogenesis: Central portion, usually from 5 to 7 mm. in diameter, is yellowish white. The central portion of the colony is surrounded by a vitreous zone, which in turn is surrounded by a light grayish white rim.
Internal structure: Granular.
Edge: Erose.

Peptone starch agar, 5 days.
Form: Irregularly round.
Size: 5 to 8 mm.
Enzymic zone: 1 to 2 mm. in 5 days; 3 to 4 mm. in 10 days.
Elevation: Flat.
Consistency: Soft in 5 days; older colonies become firm.
Chromogenesis: Central portion, usually 2 to 3 mm. in diameter, opaque white. The opaque portion of the colony is surrounded by a vitreous zone, which in turn is surrounded by a thin semi-transparent grayish white rim.
Internal structure: Granular.
Edge: Undulate.

Beef agar, 5 days.
Form: Round.
Size: Surface colonies, 1 to 1.5 mm.; bottom colonies, 2 to 3 mm.
Elevation: Slightly convex.
Consistency: Soft to butyrous.
Chromogenesis: Reflected light, grayish white; transmitted light, the colonies appear as semi-transparent glistening drops.
Internal structure: Granular.
Edge: Entire.

Potato agar, 5 days.
Form: Round.
Size: 1 to 2 mm.
Elevation: Convex.
Consistency: Very soft.
Chromogenesis: Grayish white, frequently develops brownish rings.
Internal structure: Granular.
Edge: Entire.

11. *Filter paper broths,* 15 days. Paper is reduced to a loose flocculent mass which disintegrates very readily on slight agitation. Paper is decomposed rapidly when the broths contain ammonium sulphate, potassium nitrate, peptone, or casein as the source of nitrogen.

III. BIOCHEMICAL FEATURES.

12. *Dunham's solution,* 10 days. No ammonia formed; nitrite formed.
13. *Starch nitrate solution,* 10 days. No ammonia formed; no nitrite formed.
14. *Peptone nitrite solution,* 10 days. No indol formed.
15. *Carbohydrate broths,* 12 days. No gas produced. Per cent of acidity (Fuller's Scale) with: Dextrose, .30; Lactose, .10; Saccharose, .00; Maltose, .20; Glycerine, .00; Mannite, .00; Starch, .30.

Pseudomonas minuscula, n. sp.

SOURCE: Soil from Bonita, California; Lordsburg, California; and Sanger, California.

I. MORPHOLOGY.

1. Vegetative cells: Average dimensions, .9 x .5 μ.
2. Endospores: None observed.
3. Flagella: 1, rarely 2 in number; 3 to 4 μ in length.
4. Staining reactions: Gram positive. Stains readily with the aniline dyes.

II. CULTURAL CHARACTERISTICS.

5. Agar strokes, 5 days.
   Beef agar: Moderate, flat, grayish white, filiform growth.
   Potato agar: Abundant, moist, glistening, grayish to yellowish white.
   Peptone starch agar: Moderate, grayish white, filiform growth.
6. *Potato cylinders:* No apparent growth after 30 days, but potato is bleached along the track of the inoculating needle.
7. *Gelatin stab:* Moderate growth at surface and along track of needle in 6 days; slight napiform liquefaction after 30 days.
8. *Beef broth,* 5 days: Turbid.
9. *Litmus milk:* Reddened in 6 days; neither coagulated nor digested in 30 days.
10. Plate cultures.
    Ammonia cellulose agar, 15 days.
    Form: Round or irregularly round.
    Size: Surface colonies 1 to 2 mm.; bottom colonies may attain a diameter of 6 to 10 mm.
    Enzymic zone: 1.5 to 2 mm.
    Elevation: Slightly depressed.
    Consistency: Soft.
    Chromogenesis: Nucleus and rim are white, remainder of colony grayish white.
    Internal structure: Granular.
    Edge: Undulate.
    Peptone cellulose agar, 15 days.
    Form: Round or irregularly round.
    Size: 1 to 2 mm.; bottom colonies frequently attain a diameter of 10 mm.
    Enzymic zone: 1 to 1.50 mm.
    Elevation: Slightly convex.
    Consistency: Soft.
    Chromogenesis: White to grayish white.
    Internal structure: Granular.
    Edge: Erose.

Peptone starch agar, 5 days.
Form: Irregular, round.
Size: 1 to 1.5 mm.
Enzymic zone: 2 to 3 mm.
Elevation: Slightly convex.
Consistency: Firm.
Chromogenesis: White to light grayish white.
Internal structure: Granular.
Edge: Lacerate.

Beef agar, 5 days.
Form: Round.
Size: 1 mm. or less.
Elevation: Slightly convex.
Consistency: Butyrous; old colonies become brittle.
Chromogenesis: By reflected light colonies are gray white; by transmitted light they appear as light, semi-transparent smoky drops.
Internal structure: Finely granular.
Edge: Entire.

Potato agar, 5 days.
Form: Round.
Size: 1 to 2 mm.
Elevation: Convex.
Consistency: Soft.
Chromogenesis: Gray-white, sometimes showing concentric structure.
Internal structure: Granular.
Edge: Entire.

11. *Filter paper broths*, 15 days. Paper reduced to a felt-like grayish white mass which breaks up into small particles on very slight agitation. Paper destroyed more rapidly in solutions containing ammonium sulphate, peptone, or potassium nitrate than in solutions containing casein.

III. BIOCHEMICAL FEATURES.

12. *Dunham's solution*, 10 days. No ammonia produced; nitrite produced.
13. *Starch nitrate broth*, 10 days, No ammonia produced; nitrite produced.
14. *Peptone nitrite solution*, 10 days. Indol produced.
15. *Carbohydrate broths*. No gas produced. Per cent of acidity (Fuller's Scale) with: Dextrose, 1.20; Lactose, 1.10; Saccharose, 1.00; Maltose, 1.10; Glycerine, .00; Mannite, .00; Starch, .90.

Pseudomonas mira, n. sp.

SOURCE: Soil from Corona, California; Glendora, California; Monrovia, California.

I. MORPHOLOGY.

1. Vegetative cells: Average dimensions, 1.6 x .4 μ.
2. Endospores: None observed.
3. Flagella: 1 in number; 4 to 6 μ in length.
4. Staining reactions: Gram negative. Stains readily with the aniline dyes.

II. CULTURAL CHARACTERISTICS.

5. Agar strokes, 5 days.
Beef agar: Moderate, flat, grayish white, somewhat iridescent.

Potato agar: Abundant, grayish white; becomes grayish brown in 10 days.

Peptone starch agar: Abundant, moist, grayish white; in 10 days the growth at the bottom of the slope becomes flesh colored.

6. *Potato cylinder:* Moderate, grayish white, leathery growth in 15 days.
7. *Gelatin stab:* Good growth at surface and along track of needle in 6 days; no liquefaction in 30 days.
8. *Beef broth,* 5 days: Heavily clouded.
9. *Litmus milk:* Blued in 10 days; neither coagulated nor digested in 30 days.
10. Plate cultures.

Ammonia cellulose agar, 15 days.

Form: Round or irregularly round.
Size: 1 to 1.5 mm.
Enzymic zone: 1 to 2 mm. in 15 days; 3 to 4 mm. in 30 days.
Elevation: Slightly convex.
Chromogenesis: Surface colonies opaque white; bottom colonies semi-transparent grayish white.
Internal structure: Granular.
Edge: Erose.

Peptone cellulose agar, 15 days.

Form: Round to irregularly round.
Size: Surface colonies, 1 to 2 mm.; bottom colonies 6 to 8 mm.
Enzymic zone: 1 mm. or less in 15 days; 2 to 3 mm. in 30 days.
Elevation: Slightly convex.
Chromogenesis: Surface colonies have a small white nucleus, remainder of colonies grayish white.
Internal structure: Granular.
Edge: Entire to undulate.

Peptone starch agar, 5 days.

Form: Irregularly round.
Size: 2 to 3 mm.
Enzymic zone: 1.5 to 2 mm.
Elevation: Slightly convex.
Consistency: Firm.
Chromogenesis: White to light grayish white; sometimes shows a small white nucleus.
Internal structure: Granular.
Edge: Lacerate.

Beef agar, 5 days.

Form: Surface colonies are round; bottom colonies spread profusely.
Size: 2 to 3 mm.
Elevation: Convex.
Consistency: Soft to butyrous.
Chromogenesis: Small white nucleus, remainder gray-white.
Internal structure: Granular.
Edge: Lacerate.

Potato agar, 5 days.

Form: Round.
Size: 2 to 5 mm.
Elevation: Convex.

Consistency: Very soft.
Chromogenesis: Glistening, grayish white; surface colonies have a pearl-like luster.
Internal structure: Granular.
Edge: Lacerate.

11. *Filter paper broths,* 15 days. Paper attacked along the edge nearest surface of solution; in 20 days the paper is very completely disintegrated. The paper decomposed at about the same rate in solutions containing ammonium sulphate, potassium nitrate, peptone, or casein as the source of nitrogen.

III. BIOCHEMICAL FEATURES.

12. *Dunham's solution,* 10 days. Ammonia produced; no nitrite produced.
13. *Starch nitrate solution.* Ammonia produced; nitrite produced.
14. *Peptone nitrite broth,* 10 days. No indol produced.
15. *Carbohydrate broths,* 12 days. No gas produced. Per cent of acidity (Fuller's Scale) with: Dextrose, 1.25; Lactose, .50; Saccharose, 1.10; Maltose, 1.20; Glycerine, .30; Mannite, .25; Starch, 1.50.

SUMMARY OF SPECIFIC CHARACTERISTICS OF CELLULOSE-DISSOLVING BACTERIA

The detailed description of the cellulose-dissolving bacteria known today are scattered through several publications. In the identification of newly isolated forms or in comparing the specific characteristics of described forms, it is obviously desirable that the more important morphological and cultural features of the cellulose-dissolving organisms known at this time be brought together in such a way as to afford a ready comparison. The more important morphological and cultural features of the cellulose-dissolving bacteria are briefly summarized in Table II. The biochemical reactions of the different species are summarized in Table III.

PROVISIONAL KEY FOR IDENTIFYING AND COMPARING SPECIES OF BACTERIA WHICH DISSOLVE CELLULOSE

In order to facilitate further the identification and classification of cellulose-dissolving bacteria a diagrammatic key has been prepared. In the preparation of a key of this character, it is desirable to use single diagnostic features by means of which the organisms may be separated into smaller and smaller groups until all species are finally separated from each other. In such an arrangement, it is obvious that the features used must have a high degree of constancy. In the preparation of the following key, only those features which have remained constant through a number of cultures have been used and it is believed that when the key is used in conjunction with the data presented in Tables II and III, it will be found of much help in separating a particular organism from its congeners or in assigning it a provisional place in a system of classification.

IMPORTANCE OF CELLULOSE DESTRUCTION IN SOILS.

All organisms make up for the waste incurred in their vital activities by the consumption of chemical energy. This necessary energy is for the

TABLE II

COMPARATIVE SUMMARY OF THE MORE IMPORTANT MORPHOLOGICAL AND CULTURAL FEATURES OF CELLULOSE-DISSOLVING BACTERIA

	Morphology				Cultural features							
					Beef agar					Litmus milk		
	Dimensions in microns	Number of flagella	Spores	Involution forms	Luxuriant growth	Yellow chromogensis	Broth clouded	Gelatin liquefied	Growth on potato	Milk reddened	Milk blued	Coagulated or digested
B. albidus	1.0 x .4	1-3	—	—	—	—	—	—	—	+	—	—
B. almus	1.2 x .5	1-5	—	—	—	+	+	+	—	+	—	—
B. amylolyticus (28)	3.5 x .7	10-16	+	—	+	—	+	+	—	+	—	—
B. aurogenus (29)	1.4 x .4	1-3	—	—	+	+	+	+	—	+	—	—
B. bibulus (42)	1.3 x .4	1-4	—	—	+	—	+	+	+	+	—	+
B. biazoteus (29)	.8 x .5	1-3	—	—	+	+	+	+	+	+	—	—
B. caesius (29)	1.5 x .4	1-2	—	—	—	—	+	+	—	+	—	—
B. cellaseus (29)	1.2 x .5	1-3	—	—	—	—	—	+	—	+	—	+
B. concitatus	1.2 x .5	1-3	—	—	+	+	+	+	—	+	—	—
B. cytaseus	2.7 x .5	10-18	+	+	—	—	—	—	—	—	—	—
B. desidiosus	1.0 x .4	1-3	—	—	—	—	+	—	—	+	—	—
B. festinus	2.0 x .6	1-3	+	—	—	—	—	—	—	+	—	+
B. galbus (29)	1.0 x .4	1-3	—	—	+	+	+	+	—	+	—	—
B. gelidus (29)	1.2 x .4	1-3	—	—	+	—	+	—	+	+	—	+
B. gilvus	1.5 x .5	1-4	—	—	—	+	+	—	+	+	—	—
B. imminutus	1.5 x .2	1-5	+	+	—	—	—	—	—	—	—	—
B. iugis	1.4 x .4	1-3	—	—	—	—	+	+	+	+	—	—
B. pusilus (29)	1.1 x .6	1-3	—	—	—	—	+	—	—	+	—	—
B. rossicus (28)	1.2 x .3	1-5	—	+	+	—	+	+	+	—	+	—
B. subalbus	.8 x .4	1-3	—	—	+	—	+	—	—	+	—	—
Bact. acidulum (29)	1.0 x .3	—	—	—	—	—	—	—	—	+	—	—
Bact. castigatum	1.2 x .4	—	—	—	+	—	+	—	—	+	—	—
Bact. fimi (42)	.9 x .4	—	—	—	+	—	+	+	+	+	—	—
Bact. flavigenum (28)	1.0 x .4	—	—	—	+	+	+	+	+	+	—	—
Bact. idoneum	1.5 x .5	—	—	—	—	+	+	+	+	+	—	—
Bact. liquatum (42)	1.7 x .4	—	—	—	+	+	+	+	+	+	—	—
Bact. lucrosum	1.3 x .4	—	—	—	+	—	+	—	—	—	—	—
Bact. paludosum	1.5 x .4	—	+	—	+	—	+	+	+	+	—	—
Bact. udum (29)	1.5 x .5	—	—	—	+	—	+	+	+	+	—	—
Ps. arguta	.8 x .3	1-2	—	—	—	—	+	—	—	+	—	—
Ps. effusa (29)	1.7 x .4	1-6	—	—	+	+	+	+	+	—	+	+
Ps. minuscula	.9 x .5	1-2	—	—	+	—	+	+	—	+	—	—
Ps. mira	1.6 x .4	1	—	—	+	—	+	—	+	—	+	—
Ps. perlurida (29)	1.0 x .4	1-3	—	—	+	—	+	+	+	+	—	+
Ps. subcreta (42)	1.4 x .4	1-5	—	—	—	—	—	—	—	—	—	—
Ps. tralucida (29)	1.2 x .6	1-2	—	—	—	—	+	—	—	+	—	—

most part derived from the oxidation of carbon. Green plants through the agency of their chlorophyll have the power of utilizing the radiant energy of the sunlight to decompose the carbon dioxide of the air and use it in their metabolic processes. These plants receive thereby not only the necessary energy for their own life, but store up an enormous quantity of potential energy upon which animals and those plants which do not contain chlorophyll are largely dependent. Moreover, the successful growth

TABLE III

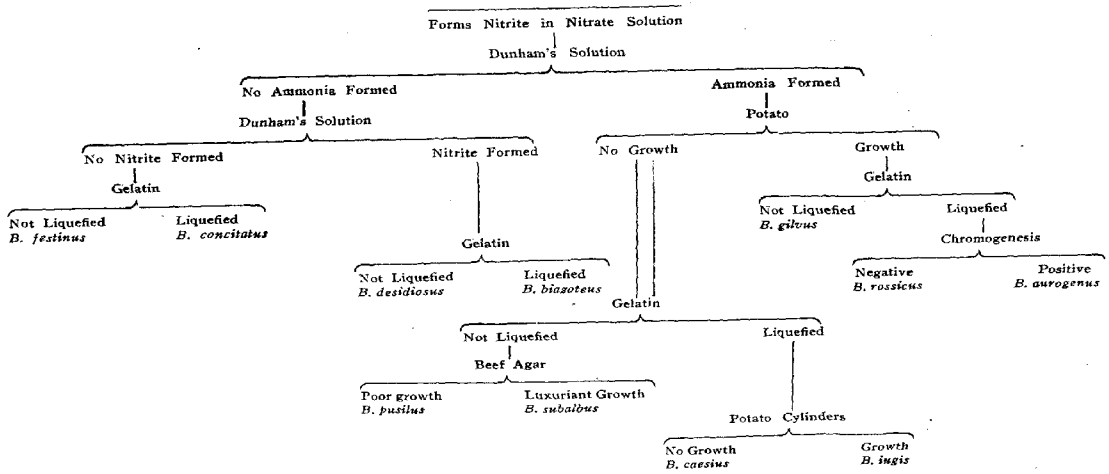
COMPARATIVE SUMMARY OF THE BIOCHEMICAL FEATURES OF CELLULOSE-DISSOLVING BACTERIA

		Dunham's solution		Nitrate solution			Per cent acid produced in 12 days at 30° C.						
		Ammonia	Nitrite	Ammonia	Nitrite	Indol	Dextrose	Lactose	Saccharose	Maltose	Glycerine	Mannite	Starch
B. albidus		—	—	—	—	—	0.50	0.20	0.10	0.10	0.10	0.10	0.10
B. almus		—	—	—	—	—	1.30	0.80	1.00	1.20	0.40	0.00	0.60
B. amylolyticus	(28)	—	—	—	—	—	0.90	0.90	0.90	0.80	0.90	0.90	1.40
B. aurogenus	(29)	+	+	+	+	—	1.80	1.40	1.40	1.20	0.70	0.00	1.60
B. bibulous	(42)	+	+	—	—	+	1.80	1.30	1.50	1.50	0.40	1.20	2.00
B. biazoteus	(29)	—	+	—	+	—	2.00	1.10	1.00	0.90	0.50	0.00	1.50
B. caesius	(29)	+	+	+	+	—	1.90	1.50	1.40	1.10	0.50	0.20	1.40
B. cellaseus	(29)	—	+	—	—	—	1.40	0.40	1.40	0.80	0.30	1.10	1.20
B. concitatus		—	—	—	+	+	1.80	0.85	1.30	1.30	0.45	0.00	1.35
B. cytaseus		—	—	—	—	—	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B. desidiosus		—	+	—	+	+	0.80	0.10	0.00	0.60	0.00	0.00	0.20
B. festinus		—	—	—	+	+	0.50	0.40	0.00	0.65	0.05	0.00	0.60
B. galbus	(29)	+	+	—	—	+	1.40	1.30	1.20	1.30	1.20	0.00	1.30
B. gelidus		+	+	—	—	—	1.20	1.20	0.80	1.20	0.40	0.00	1.40
B. gilvus		+	+	—	+	+	1.20	0.75	0.80	1.00	0.40	0.00	1.00
B. imminutus		—	—	—	—	—	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B. iugis		+	+	—	+	—	0.80	1.10	1.60	1.55	0.45	0.20	1.50
B. pusilus	(29)	+	+	—	+	—	1.50	1.40	1.60	1.40	0.50	0.00	1.50
B. rossicus	(28)	+	—	—	+	—	-1.0	-1.4	-1.4	-1.6	-1.4	-1.5	-1.2
B. subalbus		+	+	—	+	—	1.60	1.00	1.40	1.20	0.70	0.20	1.40
Bact. acidulum	(29)	—	—	—	—	—	0.40	0.30	0.30	0.50	0.00	0.00	0.00
Bact. castigatum		—	+	—	—	—	1.50	1.10	1.00	1.45	0.55	0.00	1.40
Bact. fimi	(42)	+	+	—	+	+	1.60	0.90	1.60	1.40	0.80	0.00	1.60
Bact. flavigenum	(28)	—	+	—	+	—	1.00	0.90	0.70	0.90	0.30	0.10	1.40
Bact. idoneum		—	+	—	+	—	1.60	1.20	1.20	1.40	0.70	0.00	1.40
Bact. liquatum	(42)	+	—	—	+	+	1.30	1.00	1.30	1.20	0.20	0.00	1.40
Bact. lucrosum		—	+	—	—	—	0.20	0.10	0.00	0.15	0.00	0.05	0.15
Bact. paludosum		—	+	—	—	+	1.10	0.80	1.00	1.20	0.40	0.05	1.20
Bact. udum	(29)	—	+	+	+	—	1.40	1.30	1.40	1.20	0.00	0.00	1.40
Ps. arguta		—	+	—	—	—	0.30	0.10	0.00	0.20	0.00	0.00	0.30
Ps. effusa	(29)	+	—	—	+	—	2.10	-.50	-.70	0.60	0.30	0.20	1.20
Ps. minuscula		—	+	—	+	+	1.20	1.10	1.00	1.10	0.00	0.00	0.90
Ps. mira		+	—	—	+	—	1.25	0.50	1.10	1.20	0.30	0.25	1.50
Ps. Perlurida	(29)	+	—	—	—	—	1.80	1.50	1.50	1.20	0.60	1.50	2.00
Ps. subcreta	(42)	—	—	—	—	—	0.60	0.50	0.10	0.50	0.00	0.00	0.60
Ps. tralucida	(29)	—	+	—	+	—	1.30	0.70	1.60	1.00	0.40	0.20	1.60

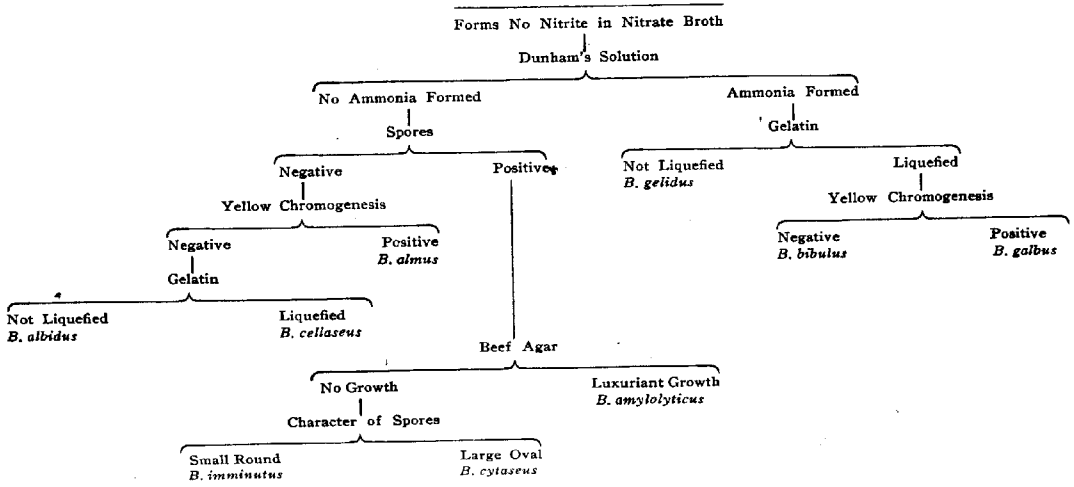
of future generations of green plants is largely controlled by the liberation of this large store of potential energy through decomposition processes in the soil.

It is well known that through the agency of microörganisms, vegetable matter is gradually transformed into the complex mixtures ordinarily known as humus. In all cultivated soils, it is important to replenish from time to time the organic matter in the soil by the application of stable manure, green manure, etc. In semi-arid soils where the growth

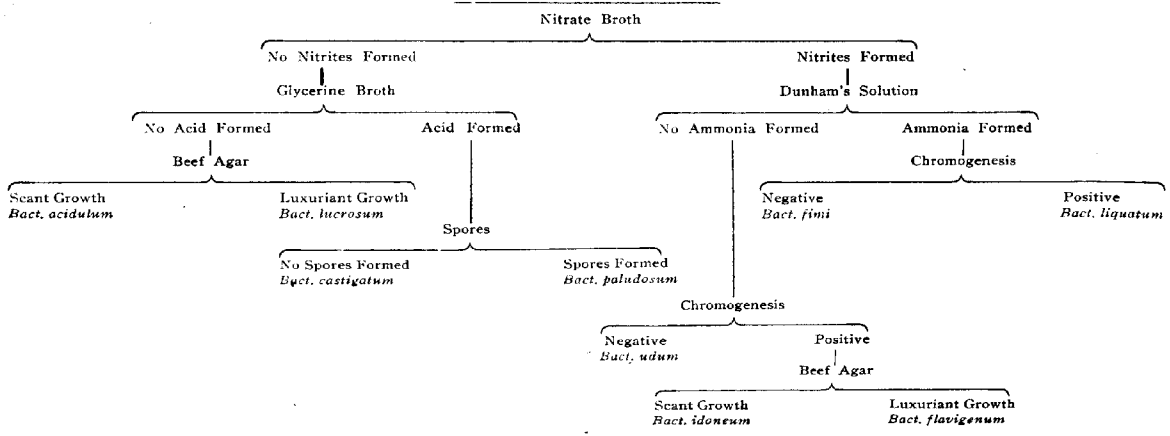
PROVISIONAL KEY FOR IDENTIFYING AND COMPARING SPECIES OF BACTERIA WHICH DISSOLVE CELLULOSE
GENUS *BACILLUS*, Part I



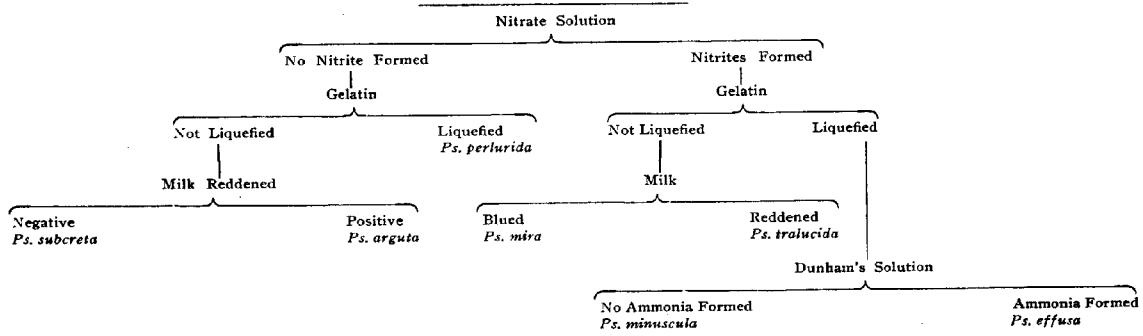
PROVISIONAL KEY FOR IDENTIFYING AND COMPARING SPECIES OF BACTERIA WHICH DISSOLVE CELLULOSE
GENUS *BACILLUS*, Part II



PROVISIONAL KEY FOR IDENTIFYING AND COMPARING SPECIES OF BACTERIA WHICH DISSOLVE CELLULOSE
GENUS *BACTERIUM*



PROVISIONAL KEY FOR IDENTIFYING AND COMPARING SPECIES OF BACTERIA WHICH DISSOLVE CELLULOSE
GENUS *PSEUDOMONAS*



of native vegetation has been limited by the meager rainfall, the humus content of the virgin soil may be as low as 0.30 per cent or even less. When such soils are brought under intensive cultivation by means of irrigation, the scarcity of humus soon manifests itself by the development of injurious changes in the tilling qualities of the land. Many such lands soon fail to give satisfactory crops or respond to the application of commercial fertilizers unless the supply of organic matter is maintained by liberal applications of barnyard manure, green manures, etc.

As the larger part of carbonaceous matter added to soils in plant residues, stable manure, etc. is cellulose,—the gradual decomposition of the cellulose in soils in association with the nitrogenous compounds must play a very prominent rôle not only in maintaining the humus content of soils, but in securing the proper development of the many important biological processes. The humus content of the soil is considered by many to serve as the depository of the insoluble nitrogen of the soil which constitutes the reserve supply for crops. It is probable but not certain that this insoluble nitrogen through the process of nitrification furnishes the main nitrogen supply to plants. The fixation of atmospheric nitrogen in the soil is dependent upon the development of microörganisms which requires large quantities of organic carbon as food. During recent years, investigations by Koch (34), Pringsheim (63), and McBeth (42) have shown that cellulose may serve as a valuable source of energy for these organisms. However, cellulose is an extremely inert compound and the carbon contained therein can be utilized by the nitrogen fixing bacteria only after the cellulose has been converted into less refractory compounds by the cellulose-dissolving bacteria. It is obvious, therefore, that the work performed by these organisms is of fundamental importance in releasing the great store of energy locked up in cellulose. In view of the fact that the cellulose added to the soil represents a large amount of potential energy, the value of which depends upon the nature of the compounds formed in its decomposition, it becomes quite important to inquire into the nature of the compounds produced by the cellulose-dissolving bacteria. Earlier investigations by Popoff (61), Toppeiner (78), Hoppe-Seyler (25), Gayon (15), Deherain (13), Schloesing (74), Van Senus (76), Omeliansky (50), and others seemed to indicate that cellulose undergoes a direct gaseous fermentation in which a very large percentage of the carbon is converted into carbon dioxide and methane. Hoppe-Seyler was of the opinion that cellulose was dissolved according to the following formula:

(1) The hydration of the cellulose with the formation of a hexose,

$$C_6H_{10}O_5 + H_2O = C_6H_{12}O_6;$$ and

(2) The destruction of the carbohydrate with the formation of equal quantities of carbon dioxide and methane,

$$C_6H_{12}O_6 = 3CO_2 + 3CH_4.$$

If cellulose undergoes a direct gaseous fermentation in which a large part or all of the carbon is returned to the air in the first decomposition processes, the addition of cellulose to the soil would undoubtedly be of far less value than if the decomposition products formed by the cellulose-dissolving bacteria were non-volatile and remain in the soil, where they may assist in maintaining the humus content or may serve as a source of energy for important groups of bacteria, such as the nitrogen fixing organisms.

It is well known that fermentation processes in the soil resulting in a decomposition of the organic matter may give rise to large quantities of CO_2 and CH_4. However, we have been unable to show that these compounds are due to the activity of cellulose-dissolving bacteria. None of the cellulose-dissolving forms studied in our investigations give rise to gaseous products in cellulose or sugar solutions in which they make a luxuriant growth. Under natural conditions the compounds formed by the cellulose-dissolving bacteria will of course be seized upon by a host of other microörganisms and split up into simple compounds. In some soils the destruction may be extremely rapid and complete, resulting in the formation of little humus; under such conditions a very large percentage of the carbon in the cellulose is quickly liberated as CO_2. However, the CO_2 formed is presumably due in all cases to secondary fermentations by the action of the organisms upon the products produced by the cellulose-dissolving organism. Likewise, the organic acids noted by early investigators were, for the most part at least, presumably due to secondary fermentation and not to the action of the cellulose-dissolving forms.

The influence of the products of bacterial activity in rendering soluble various essential mineral constituents of the soil has come to be recognized as of considerable importance in maintaining the fertility of soils. It would seem that the insoluble compounds of potassium, phosphorus, magnesium, calcium, iron, sulphur, and even silicon may be rendered soluble through the production of carbon dioxide and organic acids which result from the decomposition of cellulose and other organic matter in soils. It is well known that limestones are quickly dissolved by carbonated waters, even granite and rocks related to it are attacked because of the feldspar minerals which contain potash, sodium and calcium together with aluminum. The results of this action would seem to be highly important in many western soils as the liberation of the aluminum results in the formation of clay which has an important influence on the physical condition of the soil, while the potassium is one of the essential nutrients of plant growth.

Phosphoric acid is so tenaciously held by most soils that ordinary leaching of the soil due to natural rainfall or irrigation would seem to bring very small amounts of this valuable substance into solution. The action of carbon dioxide upon the insoluble phosphorus compounds of the soil may proceed as follows:

$$Ca_3(PO_4)_2 + 2CO_2 + 2H_2O = Ca_2H_2(PO_4)_2 + Ca(HCO_3)_2$$

A large portion of the CO_2 resulting from the decomposition of cellulose or other carbonaceous materials in soils is ultimately returned to the atmosphere where it may be used over and over again in the manufacture of sugar, starches, cellulose, etc. in new generations of plants. If it were not for the activity of cellulose-dissolving organisms in the soil developing in association with gas producing organisms, the cycle of change to which carbon is subject would soon come to a standstill and the carbon supply of plants soon be depleted.

The importance of cellulose destruction in soil may then be summarized as follows:

1. The decomposition of cellulose under proper soil conditions and in association with the nitrogenous compounds of plant tissues makes possible the maintenance of the soil humus which is so essential in maintaining the proper tilling qualities of the land.

2. The cellulose added to the soil represents a large amount of potential energy which must have a marked stimulating effect on nitrogen fixation and many other important biological processes going on in the soil.

3. The decomposition of cellulose in soils, under proper conditions, results in the formation of large quantities of carbon dioxide. The action of carbonic acid in rendering available various mineral constituents of the soil is recognized as an important factor in the maintenance of soil fertility.

4. Through the decomposition processes, the carbon locked up in the cellulose is ultimately returned to the atmosphere, thus maintaining the carbon cycle and rendering the carbon supply for plants inexhaustible.

SUMMARY

1. The cellulose agar plate method is the most satisfactory for isolating pure strains of bacteria, filamentous fungi or Actinomyces which have the power of dissolving cellulose.

2. In the preparation of precipitated cellulose for cellulose agar, the copper-ammonium-cellulose solution as well as the acid used should be very dilute. If either of the solutions are too concentrated, the precipitate is likely to be coarse, which not only makes it difficult to wash, but unsatisfactory for the preparation of culture media. A uniformly fine cellulose precipitate can be secured by diluting one part of the copper-ammonium-cellulose solution with forty parts of water and mixing with

a dilute hydrochloric acid solution, prepared by adding one part of concentrated acid to twenty parts of water.

3. Cellulose agar can be prepared from the cellulose in plant tissues by grinding the dry plant substances to a flour and isolating the cellulose in a pure state from the finely ground substance. Cellulose prepared in this way is quite as satisfactory for the preparation of cellulose agar as that prepared from filter paper in the ordinary way.

4. Twenty-five species of cellulose-dissolving bacteria have been grown on culture media containing cellulose prepared from alfalfa flour. All of the organisms plated to this medium dissolved the cellulose as readily as that prepared from filter paper.

5. All of the cellulose-dissolving organisms studied develop most rapidly in the presence of air, although more or less growth can be secured under anaerobic conditions.

6. Most of the cellulose-destroying bacteria grow well upon ordinary culture media. A few forms do not grow upon ordinary culture media, but only upon media containing cellulose.

7. The cellulose-dissolving bacteria assimilate nitrogen from organic as well as inorganic nitrogenous compounds. Many forms destroy cellulose rapidly when the culture medium contains nitrogen in the form of peptone, ammonium sulphate, potassium nitrate or casein. Peptone appears to be most favorable for the largest number of species, while casein is usually least favorable of the nitrogen compounds tested.

8. The quantity of acid formed in carbohydrate broths, in 12 days at 30° C. usually amounts to from 1 to 2 per cent on Fuller's scale, with dextrose, lactose, maltose, saccharose, and starch. The per cent of acidity in mannite and glycerine solutions is usually less than 1 per cent and in many instances no acid is formed from these substances.

9. Many species of cellulose-dissolving bacteria produce a small quantity of nitrite in Dunham's solution. The nitrite is presumably formed from the peptone. A starch nitrate broth free from peptone has therefore been used instead of the standard nitrate broth for determining the nitrate reducing power of these organisms.

10. Filamentous fungi play a much more important rôle in the destruction of cellulose in the humid soils of the eastern part of the United States than in the semi-arid soils of southern California.

11. Species of cellulose-dissolving Actinomyces have a wide distribution in soils and are unquestionably a factor in the destruction of cellulose in nature.

12. The very rapid destruction of cellulose which occurs in many soils of southern California is probably due to favorable climatic and cultural conditions which make possible the rapid development of the cellulose-dissolving organisms rather than to the unusually active nature of the cellulose-dissolving soil flora.

ACKNOWLEDGEMENTS

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THE INFLUENCE OF LIME ON THE YIELD AND NITROGEN CONTENT OF CORN[1]

By A. W. BLAIR, *Associate Soil Chemist*, AND H. C. MCLEAN, *Assistant Soil Chemist, New Jersey Agricultural Experiment Station*[2]

The practice of using lime in some one or another of its forms, for agricultural purposes, is very old. European countries recognized the value of such materials centuries ago, even before the Christian Era. In this country their value was recognized by individuals here and there throughout the first half of the nineteenth century and even earlier, but it is only within the last twenty or thirty years that the use of these materials has become very general.

Used in a judicious manner there is no question as to the beneficial effects of lime, over widely separated areas of the country and on a great variety of soils. There are comparatively few crops grown in the older sections of the country, where the soils are not naturally well supplied with carbonate of lime, that do not respond to periodic applications of lime.

Even soils of limestone origin, under long continued cultivation, may become so exhausted of their lime compounds as to respond to lime treatment. There is not always agreement as to the function of the lime in connection with the soil and the growth of the plant, but there is a very general agreement as to the final result in crop yield and generally improved soil conditions.

It is probable that the cases are rare where applications of lime are required as a source of actual food for the plant. It is quite certain, on the other hand, that it has much to do with the physical condition of the soil. It is likewise true that it has an effect upon the mineral and vegetable matter of the soil and upon soil organisms. Not the least important of these effects is the part which it plays in making available plant food out of resistant organic matter. This is undoubtedly what does occur when lime is applied to soils that have become acid, but still contain a considerable supply of organic residues. Thus lime becomes an agent in improving soils deficient in available nitrogen, in this way as well as by making the conditions more favorable for those plants which, by the aid of certain organisms, store up the nitrogen of the air.

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[2] The field work in connection with this experiment was under the direction of Mr. L. F. Merrill.

It is not intended here to enter into an extended bibliography touching the subject of lime, but rather to cite a few of the more important experiments where lime has been used in connection with the corn crop.

In a report issued in 1894, Wheeler, Towar and Tucker (16) state that with 3 tons of air-slaked lime to the acre corn was injured. With smaller quantities of lime corn was slightly benefited or uninjured.

Patterson (13) found that applications of oyster-shell lime increased the yield of corn. In a later report (14) the same author states that in a rotation of corn, wheat, and timothy and clover on run down sandy loam naturally well drained, the limed plots gave larger yields than the unlimed plots, the average net return being $4.50 an acre per year.

Discussing the use of ground limestone for acid soils in Illinois, Hopkins (3) reports that as the average of twenty tests on different experiment fields, the yield of corn was increased 6.6 bushels and as an average of eighteen tests the yield of wheat was increased 4.8 bushels per acre, both of these crops being grown in rotation with legume crops on both limed and unlimed land. Hopkins recommends the use of ground limestone when it can be obtained.

Hunt (4), summarizing the results of a series of fertilizer experiments on a clay loam soil, of limestone origin, which have been carried on for twenty-five years, says, "An acid condition, proving especially injurious in later years to the corn and clover, resulted from the continued application of sulfate of ammonia. The addition of 4000 pounds of quick lime applied once in four years to the plots receiving no fertilizer has caused a decrease in yield, but when applied in connection with 6 tons of barnyard manure, the products produced were equal to those produced by an application of 10 tons of manure without lime."

Lyon and Morgan (11) discussing the effect of fertilizers applied to timothy and the corn crop following it, say, "Lime had the effect of rendering available plant nutrients in the soil but did not increase the efficiency of the fertilizers." Since the percentage of increase was greater when fertilizers were not applied, the authors regard its beneficial effect as due to the direct liberation of plant-food rather than to its neutralizing or other action.

Mooers and Robert (12), reporting on experiments conducted on a light brown-colored silt loam and a gray-colored "crayfishy" type, say, "In studying the effect of burnt lime and ground limestone applied at the rate of 2000 pounds and 4000 pounds respectively, per acre, it was observed that an increased yield of corn, oats and red clover followed the applications of lime on both types of soil." They claim that the results from the two kinds of lime were very similar, the ground limestone, however, being slightly superior.

In Bulletin 279 of the Ohio Agricultural Experiment Station, Thorne (15) reports the average results secured over a period of 12 years in a 5-year rotation of corn, oats, wheat, clover and timothy, where lime and ground limestone were used on certain of the plots while other plots received no lime. The experiments were conducted on a light silty clay which had previously been subjected to an exhausive system of farming. In a review of this work reported in Vol. 1, No. 1 of the monthly bulletin of the Ohio Station, Thorne gives a condensed table of yields and draws attention to the way in which the corn has followed the lime. "In 1900 the yield on the west end of Section E, just limed, was 8 bushels more than on the east end. In 1905, the liming was transferred to the east end and the yield was nearly 12 bushels greater than it had been on that end in 1900 while the west end limed in 1900, but not in 1905 still showed the effect of the liming although its yield was several bushels below that of the newly limed east end. Were the corn the only crop benefited by liming the cost would outweigh the gain; but the average results for the entire rotation showed that there has been a gain on the unfertilized land of 4.76 bushels of oats, 2.75 bushels of wheat, 494 pounds of clover hay and 641 pounds of timothy hay in the average of the crops following the corn, the whole having a total value of $13.82, if we value corn at half a dollar per bushel, oats at one-third of a dollar, wheat at 90 cents and hay at $10 per ton. The average cost of liming has been about $5 per acre; so there has been an ample margin of profit.

In lime tests in various parts of Alabama (1) the yield of corn was increased by the use of lime in all but three of the experiments. The average increase was 11 per cent.

Under a discussion of lime for the tidewater section of Virginia, Ellett (2) says, "Stable manure and lime increased the yield 100 per cent above commercial fertilizers alone. Lime increased the yield 39 per cent above commercial fertilizers and manure."

In a bulletin on corn experiments, Williams and Welton (18) say, "On such acid soils as are found on the station farm at Wooster, 1 ton of burned lime, or 2 tons of ground limestone, applied once in 5 years, has increased the yield of corn on an average 7.35 bushels per acre on the fertilized plots reported in Table III, and 8.25 bushels per acre on the unfertilized plots. Taking into consideration all the crops of the rotation the application of lime has been worth, on the average $14.21 per acre per rotation. The cost of the lime has been $5.00."

Lipman and Blair (10) have shown that lime increases the yield of dry matter (forage) and also the amount of nitrogen recovered in the crop, when corn is grown in cylinders in a regular 5-year rotation, and also when it is grown as a residual crop in the rotation.

When lime was used with a complete fertilizer, Williams, Kilgore and Russell (17) found that "On an average taking the results of both fields together, there was an increase due to the lime above the cost of the lime to the value of $2.89 per acre on the basis of corn alone and of $4.52 on the basis of corn and stover together." When used without commercial fertilizers the lime was not profitable.

The work here reported constitutes a part of a regular 5-year rotation of corn, oats, oats, wheat, and timothy that is being conducted at the New Jersey Agricultural Experiment Station, the results of the first five years having been published (6). The corn crop here referred to was the first crop in the second rotation.

The work is suggestive and raises questions which have not been fully touched upon. For example, certain of the data presented in Table I will appear more intelligible when considered in the light of the completed rotation. A discussion of the causes which may account for the differences in the recovery and availability of nitrogen as observed, is reserved for a more detailed consideration in another paper.

The experiment was planned primarily to study the availability of nitrogen in different nitrogenous materials, but since there are two sections which receive similar treatment with respect of nitrogenous constituents, it was possible to lime one section while the other section has, all the while, remained unlimed. The lime treatment has been 1 ton of ground limestone per acre in 1908 preceeding the first crop of corn, and 2 tons per acre in 1913, preceeding the second crop of corn.

The soil was described in the publication just referred to and it is necessary here only to say that it is a loam which contains a considerable portion of small pebbles scattered through it. Prior to the beginning of this experiment the land had been neglected for a number of years.

The lime requirement of the soil was not determined when the work was begun, but that the soil was originally acid is indicated by the fact that no lime had been applied in recent years and by the further fact that notwithstanding the application of 1 ton of ground limestone per acre in 1908 the soil on all the plots was decidedly acid at the end of the first five years, no plot requiring less than 1000 pounds of lime (CaO) per acre to neutralize the acidity to a depth of about seven inches.

The influence of the first application of lime seems, however, not to have entirely disappeared, for volunteer red clover appeared on nearly all the plots following the timothy crop in 1912, and as elsewhere (6) noted there was nearly twice as much clover taken from the limed plots as from the unlimed plots. Furthermore, that from the limed plots contained, in the dry matter, about .5 per cent more nitrogen than that from the unlimed plots. Table I indicates the fertilizer treatment the different plots have received. From this it will be noted that six of the plots have

no nitrogen applied to them and that 1 A and 1 B, and 7 A and 7 B receive neither nitrogen nor mineral fertilizers. These facts in part account for the low average yields for the 1908 and 1913 crops.

CROP OF 1908

Since this work has already been published it is necessary here to give only a brief summary of the figures. A comparison of the limed and unlimed sections gives the following average yields per acre.

		Limed	Unlimed
Grain		46.00	39.31 bu. per acre
Stover		3466.20	2948.60 lbs. per acre
Nitrogen removed in crop	Grain	37.52	32.30 lbs. per acre
	Stover	27.78	23.22 lbs. per acre
Nitrogen in dry matter	Grain	1.45	1.46 per cent
	Stover	.796	.79 per cent
Nitrogen recovered in crop		33.23	12.80 per cent

From these figures it will be observed that the limed section gave higher results than the unlimed in all cases except the percentage of nitrogen in the dry matter, grain and stover, which is practically the same in both sections. The increase in yield of grain alone would more than pay for the lime that was used for the entire rotation. Furthermore, it is entirely possible that a heavier application of lime in 1908 might have made even a greater difference between the two sections, for as already noted the first application of ground limestone was not sufficient to keep the soil neutral throughout the rotation and it has already been shown by many experiments conducted in this country and also abroad, that the remaining crops used in this rotation normally respond to lime treatment, whereas in this case the yields of oats, wheat and timothy were just about as good on the unlimed as on the limed sections.

That the increased yield of corn in the limed plots was due in part, at least, to a larger supply of available nitrogen resulting from a more thorough nitrification of the soil organic matter, is made clear by a comparison of the yields on certain plots which received an extra supply of nitrogenous materials, with the yield from certain other plots which received a limited supply of nitrogen. It will be noted, for example, that plots 5 and 6, and 18 and 20 in both sections received an extra supply of nitrogen in the form of manure or nitrate of soda or both, and on these plots the lime did not result in any greater average increase in yield than it did on plot 15 B for example which received only 49 pounds of nitrogen. This probably means that an excess of available nitrogen was applied to plots 5, 6, 18 and 20 and therefore that which was made available by the lime applied to these plots in the B section did not influence the crop yield. Furthermore, the basic materials furnished by the manure, and the soda furnished by the nitrate of soda would tend to obliterate the effect of the lime.

Crop of 1913

The differences in the yield for this year are even more pronounced than in the crop of 1908. However, it will be remembered that preceeding the 1913 crop the plots in the limed section received ground limestone at the rate of 2 tons per acre. The curves in figure I, show the lime requirement of the various plots before this application was made.

The yield of dry matter and other data for the second rotation are set forth in Table I.

Referring to the column marked "Nitrogen Applied" it will be noted that in the case of certain plots 5, 6, 16, 17, 18 and 20, both sections, much more nitrogen was applied than was applied to the other plots which call for a nitrogen treatment. This is due to the fact that for the former plots the plan calls for a definite amount of nitrogenous fertilizer, as manure or other organic material, rather than a definite amount of nitrogen, as in a majority of the nitrogen treated plots.

The Yield of Dry Matter

With the exception of plots 1, 5, and 6, the limed sections gave the largest yield of grain, and with the exception of plots 1, 2, 3, 6 and 18, likewise the largest yield of stalks. In the case of 5, 6, and 18, the explanation for this seems to lie in the fact that for these plots, the manure and nitrate of soda furnished a sufficient amount of available nitrogen and also a certain amount of basic materials so that the crop was not dependent on the nitrogen that was made available by the lime. No definite reason is at present assigned for the failure of 1 B, 2 B and 3 B to yield as much grain as 1 A, 2 A and 3 A.

It is of interest to compare plots 17 A and 17 B. These plots received wheat straw or rye straw as a source of nitrogen. These materials are low in nitrogen, and besides, when used on an acid soil, they lie in that soil more or less inert very much like the organic matter that is already in the soil. On the other hand, when used in connection with some form of lime as in 17 B, they decompose much more rapidly, thus yielding available nitrogen. At the same time the lime acts on the soil organic matter also, making some of the nitrogen available. Thus the yield on 17 A is at the rate of 19.2 bushels of grain and 2000 pounds of stalks while the yield on 17 B is 46.4 bushels of grain and 2525 pounds of stalks per acre. Furthermore, the percentage of nitrogen in both grain and stalks from 17 B is higher than from 17 A.

The difference between 16 A and 16 B is not so marked for the reason that green alfalfa or alfalfa hay was used on these plots as a source of nitrogen. A given weight of this material not only furnishes more nitrogen than an equivalent weight of wheat or rye straw, but the nitrogen of the alfalfa is more available than that of the wheat straw or of the rye straw

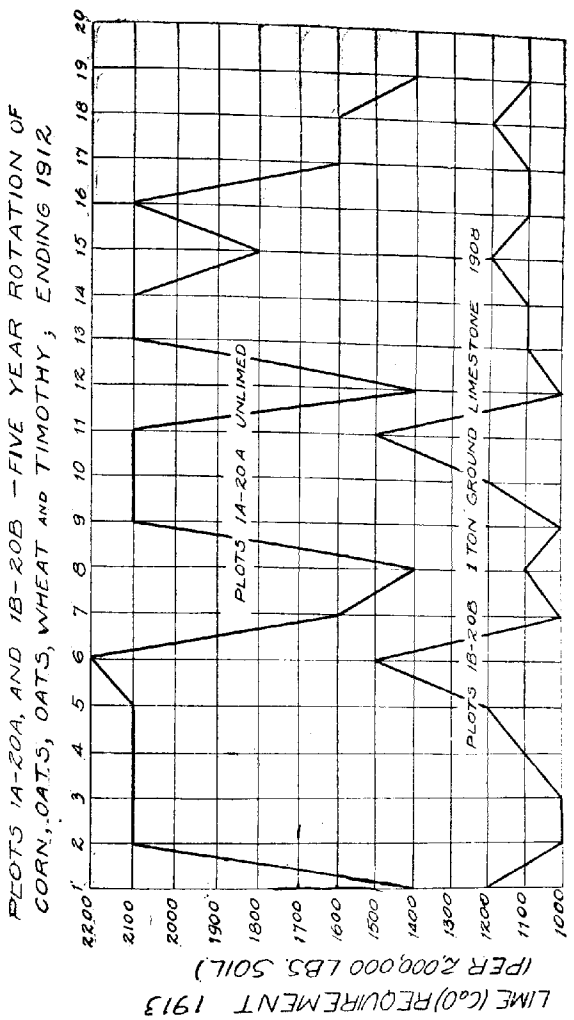

Fig. 1.—Lime requirement of soil from unlimed and limed plots.[1]

[1] Taken from Bulletin No. 260, New Jersey Agricultural Experiment Station.

TABLE I

YIELD OF DRY MATTER AND PERCENTAGE OF NITROGEN. UNLIMED SECTION 1913
(Results calculated to acre basis)

No.	Treatment	Nitrogen applied, lbs.	Dry Matter			Per Cent Nitrogen			Total Nitrogen, lbs.	Increase Over Check			Per Cent Nitrogen Recovered
			Grain, bu.	Stalks, lbs.	Cobs, lbs.	Grain	Stalks	Cobs		Grain, bu.	Stover, lbs.	Total Nitrogen, lbs.	
1A	Nothing	.....	15.180	1500	175	1.522	1.126	.573	30.840	.....	.....	.....	.....
2A	16 lbs. muriate of potash	.....	14.290	1550	150	1.413	.720	.553	23.294	.....	.....	.....	.....
3A	32 lbs. acid phosphate	.....	12.500	1600	100	1.462	.830	.741	24.255	.....	.....	.....	.....
4A	Minerals only[1]	.....	[2]11.607	[2]1775	[2]75	1.364	.781	.405	[2]23.033	.....	.....	.....	.....
5A	Minerals + 1600 lbs. cow manure	173.47	39.286	2525	325	1.590	.828	.415	57.241	27.902	962	35.363	20.38
6A	Minerals + 1600 lbs. horse manure	215.84	40.179	2950	325	1.492	.860	.366	60.130	28.795	1387	38.252	17.72
7A	Nothing	.....	7.143	875	75	1.521	.809	.711	13.696	.....	.....	.....	.....
8A	Minerals + 8 lbs. $NaNO_3$	24.50	15.625	1525	100	1.373	.611	.435	21.767	4.241	....	.....	.....
9A	Minerals + 16 lbs. $NaNO_3$	49.00	29.018	1975	225	1.541	.631	.543	38.725	17.634	312	16.847	34.39
10A	Minerals + $Ca(NO_3)_2$ equiv. to 16 lbs. $NaNO_3$	49.00	22.321	1625	200	1.550	1.006	.583	36.889	10.937	.....	15.011	30.63
11A	Minerals + $(NH_4)_2SO_4$ equiv. to 16 lbs. $NaNO_3$	49.00	23.214	1650	175	1.521	.819	.484	34.134	11.830	.....	12.256	25.01
12A	Minerals + $CaCN_2$ equiv. to 16 lbs. $NaNO_3$	49.00	25.893	2050	200	1.344	.710	.484	35.011	14.509	362	13.133	26.80
13A	Minerals + dried blood equiv. to 16 lbs. $NaNO_3$	49.00	23.661	1950	225	1.482	.720	.534	34.879	12.277	287	13.001	26.53
14A	Minerals + dried fish equiv. to 16 lbs. $NaNO_3$	49.00	29.018	2175	250	1.680	.740	.484	44.610	17.634	537	22.732	46.39
15A	Minerals + concentrated tankage equiv. to 16 lbs. $NaNO_3$	49.00	31.250	2250	225	1.492	.828	.425	45.696	19.866	587	23.818	48.61
16A	Minerals + 800 lbs. green alfalfa	147.30	35.715	2400	275	1.729	1.184	.445	54.064	24.331	787	32.186	21.85
17A	Minerals + 800 lbs. green wheat or rye	92.12	19.196	2000	125	1.640	.740	.731	33.344	7.812	237	11.466	12.45
18A	Minerals + 1600 lbs. cow manure and 16 lbs. $NaNO_3$	222.46	46.429	2975	425	1.690	.917	.395	72.900	35.045	1512	51.022	22.94
19A	Minerals only	.....	[2]11.161	[2]1800	[2]125	1.413	.612	.701	[2]20.723	.....	.....	.....	.....
20A	Minerals + 800 lbs. green wheat or rye and 16 lbs. $NaNO_3$	141.10	34.821	2400	250	1.680	.907	.573	55.961	23.437	762	24.083	17.07
	Average		24.375	1977.5	201.25	1.525	.819	.529	38.060	18.303	552.3	22.083	25.055

[1] Minerals = 32 lbs. acid phosphate and 16 lbs. muriate of potash.

[2] Nos. 4 and 19 averaged for check. Stalks + Cobs = Stover.

TABLE I—(Continued)

YIELD OF DRY MATTER AND PERCENTAGE OF NITROGEN. LIMED SECTION 1913

(Results calculated to acre basis)

No.	Treatment	Nitrogen applied, lbs.	Dry Matter			Per Cent Nitrogen			Total Nitrogen, lbs.	Increase Over Check			Per Cent Nitrogen Recovered
			Grain, bu.	Stalks, lbs.	Cobs, lbs.	Grain	Stalks	Cobs		Grain, bu.	Stover, lbs.	Total Nitrogen, lbs.	
1B	Nothing	.....	12.946	1375	150	1.600	.898	.464	24.644	.....	.....	.....	.....
2B	16 lbs. muriate of potash	.....	22.321	1425	175	1.462	1.026	.524	33.813	.....	.....	.....	.....
3B	32 lbs. acid phosphate	.....	16.518	1550	225	1.590	.957	.543	30.764	.....	.....	.....	.....
4B	Minerals only[1]	.....	[2]27.679	[2]2350	[3]175	1.413	.789	.445	[3]39.810	.....	.....	.....	.....
5B	Minerals + 1600 lbs. cow manure	173.47	38.839	2800	325	1.620	.947	.415	63.105	15.847	625	27.138	15.64
6B	Minerals + 1600 lbs. horse manure	215.84	29.464	1725	250	1.630	.967	.504	44.841	6.472	.....	8.874	4.11
7B	Nothing	.....	28.125	1875	275	1.600	1.016	.415	45.391	[3]5.133	.....	[3]9.424	.....
8B	Minerals + 8 lbs. $NaNO_3$	24.50	36.161	2100	300	1.541	.996	.494	53.603	13.169	.....	17.636	71.98
9B	Minerals + 16 lbs. $NaNO_3$	49.00	35.268	2300	350	1.600	.878	.514	53.593	12.276	150	17.626	35.97
10B	Minerals + $Ca(NO_3)_2$ equiv. to 16 lbs. $NaNO_3$	49.00	42.411	2650	325	1.531	.710	.405	56.491	19.419	475	20.523	41.88
11b	Minerals + $(NH_4)_2SO_4$ equiv. to 16 lbs. $NaNO_3$	49.00	45.536	2725	375	1.482	.878	.445	63.386	22.544	600	27.419	55.94
12B	Minerals + $CaCN_2$ equiv. to 16 lbs. $NaNO_3$	49.00	39.732	2850	325	1.581	.711	.425	56.822	16.740	675	20.855	42.55
13B	Minerals + dried blood equiv. to 16 lbs. $NaNO_3$	49.00	39.732	2700	325	1.541	.781	.454	56.851	16.740	525	20.884	42.61
14B	Minerals + dried fish equiv. to 16 lbs. $NaNO_3$	49.00	40.179	2675	325	1.541	.701	.415	54.774	17.187	500	18.807	38.38
15B	Minerals + concentrated tankage equiv. to 16 lbs. $NaNO_3$	49.00	41.964	2425	350	1.571	1.045	.385	63.608	18.972	275	27.641	56.41
16B	Minerals + 800 lbs. green alfalfa	147.30	39.286	2575	350	1.610	1.164	.425	66.881	16.294	425	30.914	20.99
17B	Minerals + 800 lbs. green wheat or rye	92.12	46.429	2525	375	1.719	1.026	.514	72.529	23.437	400	36.562	39.69
18B	Minerals + 1600 lbs. cow manure and 16 lbs. $NaNO_3$	222.46	52.679	2625	425	1.590	.967	.425	74.095	29.687	550	38.128	17.14
19B	Minerals only	.....	[3]18.304	[2]2300	[3]175	1.334	.631	.534	[3]32.123	.....	.....	.....	.....
20B	Minerals + 800 lbs. green wheat or rye and 16 lbs. $NaNO_3$	141.10	43.304	2625	400	1.699	.986	.435	68.924	20.312	525	32.957	23.36
	Average		34.844	2309	296.5	1.563	.904	.459	52.802	17.793	408.9	24.712	36.189

[1] Minerals = 32 lbs. acid phosphate and 16 lbs. muriate of potash.

[2] No fertilizer applied. Omitted from average.

[3] Nos. 4 and 19 averaged for check. Stalks + Cobs = Stover.

and the crop is supplied with nitrogen even though lime is not present to act upon resistant organic matter. Plots 7 A and 7 B received no nitrogenous fertilizers and 8 A and 8 B only a half-portion of the nitrate of soda, but 7 B and 8 B gave much larger yields than 7 A and 8 A for the reason that the lime caused a fair amount of the nitrogen of the inert soil organic matter to be brought into an available form. In the case of plot 7B which did not receive minerals, the increase is no doubt due in part to potash and phosphoric acid that were made available by the lime.

Attention may also be called to the yields on plots 11 A and 11 B, the former giving 23.2 bushels of grain and 1650 pounds of stalks and the latter 45.5 bushels of grain and 2725 pounds of stalks per acre. On plot 11 A the soil had become so acid from the continued use of ammonium sulphate that the yield was very much depressed. The lime used on plot 11 B corrected the acidity and as a result the yield was almost doubled.

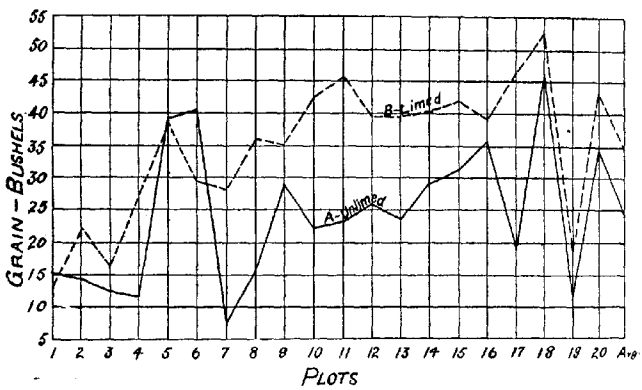

Fig. 2.—The influence of lime on the yield of corn, 1913.
(Calculated to acre basis.)

The combination of manure, nitrate of soda and lime used on 18 B resulted in a yield of 52.7 bushels of shelled corn as against 46.4 bushels on 18 A. These were maximum yields for the limed and unlimed plots, respectively, and emphasize the value of the two forms of nitrogen, that is, a slowly available material with much organic matter, and the concentrated material that is quickly available. It is very certain that this combination furnishes a large excess of nitrogen and certainly the expense of such treatment is altogether out of proportion to the returns. In this case the application of nitrogen amounted to 222.5 pounds per acre whereas with 49 pounds of nitrogen in the form of commercial nitrogenous materials a yield of about 40 bushels of corn per acre was secured.

It is true that with commercial materials only, the supply of organic matter in the soil would not be kept up indefinitely, but in an approved

rotation this can be taken care of largely by the introduction of legumes as green manure crops.

The yield of shelled corn on the two sections is indicated by curves in figure 2.

Percentage of Nitrogen in the Dry Matter

With a few exceptions the percentage of nitrogen in the grain and stalks is higher for the plots which received the large application of nitrogen than it is for those plots that received the standard application. It is true also that the average percentage of nitrogen in the dry matter in both the grain and stalks from the plots that received no nitrogen treatment is less than it is in the dry matter from the plots that received nitrogen. It is likewise true with reference to grain and stalks, that the average percentage of nitrogen in the dry matter from all plots in the limed section is greater than the average from all plots in the unlimed section.

This effort of the plant to utilize available nitrogen when present has been referred to in earlier publications (5, 10). The fact that the dry matter from the limed plots contains a higher proportion of nitrogen than that from the unlimed plots seems to be confirmatory evidence that the lime plays a part in making available the nitrogen of the inert soil organic matter. Reference has already been made to the higher nitrogen content of clover grown on limed plots. This likewise is undoubtedly a case of more available nitrogen, but with the clover the additional nitrogen is probably drawn largely from the air, whereas in the case of the grain it must come from the soil or from applied fertilizers.

In experiments with soybeans (8, 9) on limed and unlimed plots it has been shown that the shelled beans grown on the former contain about 0.5 per cent more nitrogen than those grown on the latter, and this applies to an average obtained from some six or seven varieties. Here the lime aids those organisms that live in the plant and store up nitrogen from the air, and likewise those that live in the soil and convert dead organic matter into plant food, while in the case of the corn it probably aids the latter only. Similar observations have been made with reference to oats and peas, vetch, oats, lima beans (seed), cowpeas (hay), and timothy and clover (7, p 442-451; 8, p. 237), with the exception that the increase in most cases is not so great as with soybeans. It thus appears that lime aids in the utilization, by the crop, of a greater amount of nitrogen in the case of both leguminous and non-leguminous crops. However, with the latter this extra amount of nitrogen should be furnished by the introduction, in the rotation, of leguminous crops rather than by the purchase of nitrogenous materials.

Total Nitrogen Recovered

Since there is not a great variation in the percentage of nitrogen in the dry matter, the total nitrogen recovered in the crop will depend largely on the variation in the yields of dry matter, and as the yields were greater on the limed than on the unlimed sections, it naturally follows that the most nitrogen was recovered from the former. Of the plots that received nitrogen treatment, 6 B is the only exception to this, the yield on this plot being 44.84 pounds per acre as against 60.13 pounds on 6 A. No explanation appears for this. It received more nitrogen than 5 B and there seems no reason why it should not have yielded at least as much to the crop as 5 B.

The highest yield of nitrogen, 74.1 pounds per acre was on plot 18 B and the second highest, 72.5 pounds on 17 B. The latter is of especial interest since it is more than double the yield on 17 A, and shows in a striking manner, how lime makes the nitrogen of inert organic material—in this case rye straw—available. . . In contrast with the yield of 33.34 pounds of nitrogen per acre on 17 A, may be set the yield of 55.96 pounds on 20 A. The latter received the same amount and same kind of rye straw as 17 A but in addition to this it received also nitrate of soda at the rate of 320 pounds per acre. Thus a supply of readily available nitrogen runs the yield up even though no lime is applied. The effect of the supply of available nitrogen is likewise noted in 16 A. Here the nitrogen was furnished in the form of alfalfa hay chopped up and spread on the land before plowing, and since this furnished readily available nitrogen the yield was almost equal to the yield on 20 A which received one-third of its nitrogen in the form of nitrate of soda.

An interesting comparison may also be made between 8 A and 8 B. Plot 8 A received a very light application of nitrate of soda without lime, and yielded 23.77 pounds of nitrogen per acre in the crop. Plot 8 B received the same nitrogen treatment and also ground limestone and yielded 53.6 pounds of nitrogen per acre; as much as 9 B which received the double portion of nitrate of soda.

The high yield on both 18 A and 18 B is easily explained as a result of the heavy application of cow manure, and in addition nitrate of soda at the rate of 320 pounds per acre. These plots received nitrogen at the rate of 222.5 pounds per acre, much of it in a readily available form, while 17 A and 17 B received only 92.1 pounds, all of which was in a slowly available form. In spite of this fact 17 B, thanks to the influence of the lime, yielded almost as much total nitrogen as 18 B. The same point is brought out in the yields of nitrogen from plots 19 A and 19 B. Plot 19 A, to which no nitrogen or lime was applied, yielded nitrogen at the rate of 20.7 pounds per acre in the crop. Plot 19 B likewise received no nitrogen but it received the treatment of ground limestone and yielded

nitrogen at the rate of 32.1 pounds per acre in the crop, an increase over 19 A of more than 50 per cent.

Certainly these are not new facts, but, on the other hand, the figures do lay new emphasis upon truths which though known, have hitherto been too little regarded by the practical farmer, namely, that an abundance of phosphoric acid and potash cannot give a fair crop when nitrogen is the limiting factor and that even though there is an abundant supply of nitrogen along with the minerals, it cannot give a maximum crop if it exists in inert materials, that is, if it is not readily available during the growing period of the plant.

The average yield per acre of nitrogen for all unlimed plots was 38.06 pounds and for all limed plots 52.8 pounds.

It may well be pointed out again that the use of lime in the way indicated above carries with it the obligation of maintaining the supply of organic matter in the soil. Otherwise, a time will come when there will be little or no response to applications of lime.

Percentage of Nitrogen Recovered

The last column in the table indicates the percentage of nitrogen recovered. This is obtained by subtracting the amount of nitrogen recovered from the check plots (the average of plots 4 and 19, these having received minerals but no nitrogen) from the total nitrogen recovered from any nitrogen treated plot. The amount of nitrogen recovered from the check plots is supposed to represent the soil nitrogen which the plant used, as distinguished from the applied nitrogen. The difference represents that part of the applied nitrogen which the plant was able to utilize. Therefore, when the amount of nitrogen that was applied is known, it becomes an easy matter to calculate the percentage of nitrogen that was recovered in the crop. It may be noted, however, that the percentages thus obtained may not be an entirely true indication of the amount of applied nitrogen recovered, for the reason that the plants on the nitrogen treated plots are stimulated to a greater use of soil organic nitrogen than the plants on the check plots.

Careful examination of the recoveries for the two sections brings out a number of points of interest. For example the average recovery for the B section is 11 per cent higher than the average for the A section. Likewise the average for plots 9 to 15 inclusive—those plots that receive nitrogenous compounds in equivalent amounts—is, for the B section 44.82 per cent and for the A section 34.05 per cent, a difference in favor of the B section of nearly 11 per cent.

It is of especial interest to note the low recovery in both sections, where excessive amounts of nitrogen were used, as for example plots 5 and 6 and 18 and 20. In these cases the recoveries were low both with and without lime, indicating a large loss of the applied nitrogen. Certain

of these plots, as for example 18 A and 18 B, gave rather heavy yields of grain, as compared with other plots, at least, but the cost of the treatment is too great for the returns secured. The cost of the nitrogen alone that was applied to these plots would not be less than $20.00, perhaps nearer $30.00, under normal conditions. Certainly such heavy applications are neither profitable nor economical. They are good illustrations of the law of diminishing returns. Evidently on these plots there was so much

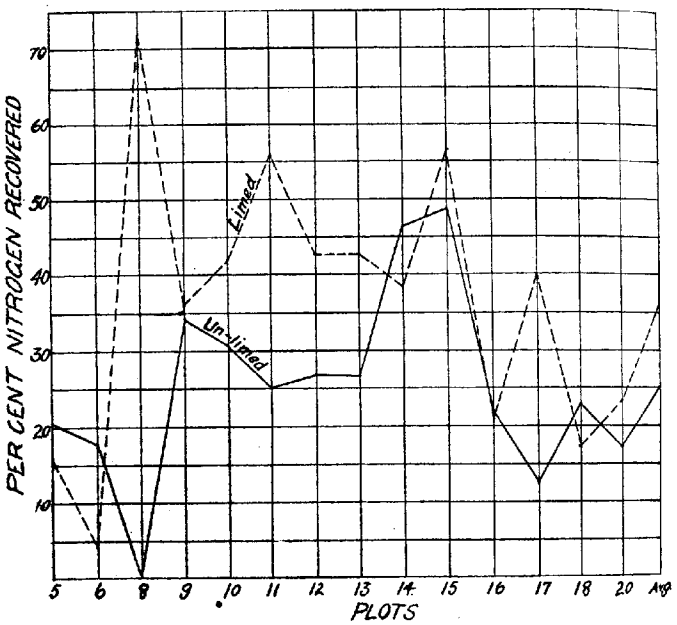

Fig. 3.—Percentage of nitrogen recovered from limed and unlimed plots: corn 1913.

available nitrogen applied that the lime did not have much influence one way or the other. In the case of plots 18 B and 20 B the possible influence of the basic effect of the soda of the nitrate of soda should not be overlooked. The heavy application of organic matter undoubtedly aided in improving the physical condition of the soil and in maintaining its supply of nitrogen, but such organic matter should be obtained in a more economical way.

The 24½ pounds of nitrogen per acre applied to plot 8 A does not seem to have been enough to increase the yield beyond the yield of the check plot, hence there was no recovery for this plot. The acid condition of the soil evidently resulted in a poor start for the corn and consequently it did not use, to good advantage, the small amount of available nitrogen that was at its disposal.

Plot 8 B, on the other hand, shows a recovery of nearly 72 per cent of the applied nitrogen. The correcting of the acidity and the improvement of the physical condition of the soil made it possible for the plant to utilize nearly three-fourths of the nitrogen that was applied.

A recovery of nearly 56 per cent of the applied nitrogen from plot 11 B, where lime was used in connection with ammonium sulfate, as against a recovery of 25 per cent on 11 A, which received the same treatment less the lime, indicates very clearly the importance of considering the reaction of the soil as a factor when ammonium sulfate is used.

Very much the same condition is noted with reference to plots 17 A and 17 B. The inert slowly available straw when used in connection with lime furnishes available nitrogen and shows a recovery on plot 17 B of 39.69 per cent as against 12.45 per cent on plot 17 A without lime.

It may be pointed out that the limed plots which receive calcium nitrate and calcium cyanamid show a higher recovery than similarly treated plots without lime.

The percentage of nitrogen recovered in the entire crop for the two sections is indicated by curves in figure 3.

SUMMARY

On a medium loam soil with a series of 20 twentieth-acre plots, arranged for a study of nitrogen availabilty, an application of ground limestone at the rate of 2 tons per acre, increased the yield of shelled corn by about ten bushels and of stover by 432 pounds per acre, as compared with the yield from a similar series of unlimed plots.

The influence of the lime on the yield from the plot which annually received its nitrogen in the form of ammonium sulphate, as compared with the yield from the similarly treated plot, unlimed, was especially marked.

The liming likewise resulted in greatly increased yields on certain of the plots which received their nitrogen in the form of rather slowly available organic materials, as, for example, wheat or rye straw. It also resulted in decided increases in the yields on plots which received minerals only, indicating that in the soil of these plots there was a considerable store of inert nitrogenous material which required only a favorable soil reaction to make it available.

Unlimed plots which received an extra heavy application of manure, or manure and nitrate of soda, gave yields fairly approaching or even surpassing the yields given by plots which received similar nitrogenous treatment and lime. That is, the manure or the basic materials in the manure and nitrate of soda apparently decreased the need for lime.

The average percentage of nitrogen in the grain and stover from the limed plots was slightly greater than the average in the grain and stover from the unlimed plots.

The average recovery of nitrogen from the limed plots was 36.2 per cent and the average from the unlimed plots was 25 per cent.

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A RAPID METHOD FOR THE ESTIMATION OF CALCIUM OXIDE IN PEAT SOILS[1]

By

ROSS AIKEN GORTNER, *Associate Soil Chemist, Minnesota Agricultural Experiment Station, St. Paul, Minnesota*

It has recently been necessary to make a large number of analyses of peat soils at this experiment station, these analyses consisting of the estimation of nitrogen, volatile matter, residue insoluble in aqua regia, phosphoric acid and lime.

The ordinary method for estimation of calcium oxide consisting of the double precipitation of the iron and the aluminum hydroxides followed by a double precipitation of the calcium oxalate, consumed so much time that it was thought advisable to see if as accurate results could not be obtained by a shorter method, i. e. the precipitation of the calcium oxalate in the presence of the iron and aluminum hydroxides and subsequent titration with potassium permanganate.

Five grams of peat were incinerated in quartz dishes, the ash digested with aqua regia and then evaporated to dryness to dehydrate the silica, the residue taken up with dilute acid and filtered into a 500-c.c. flask. The filtrate was made to volume and constitued our Solution "A". This is the method followed by the Bremen Peat Experiment Station.[2]

The methods used are here given in detail. Method 2 is essentially the method for calcium as given by Washington.[3]

METHOD 1

To 100 c.c. of Solution "A" enough ammonia is added to make the liquid smell strongly of it and to precipitate the iron and aluminum. The liquid is brought to a boil, preferably on a hot plate, and while boiling, 10 c.c. of a saturated solution of ammonium oxalate is added. By this procedure the calcium oxalate is precipitated over the surface of the iron hydroxide, making the latter more or less granular and greatly aiding filtration and washing. The boiling is cautiously continued for a couple of minutes and then the solution is allowed to cool. After at least 3 hours, (preferably over night) the solution is filtered through a 9-cm. filter (if

[1] Received for publication May 8, 1916.

[2] König, S. Untersuching Landwirtschaftlich und gewerblich wichtiger Stoffe. 9 ed., Paul Parey, p. 118-119. Berlin, 1911.

[3] Washington. The Chemical Analysis of Rocks, John Wiley & Sons, New York, 200 p., 1910.

there is only a small precipitate use a 7-cm. filter) and well washed with warm water. (A convenient test for the removal of the excess of oxalate is a solution of sulphuric acid containing 2 or 3 drops of standard permanganate solution. If 5 c.c of the washings reduces the permanganate, it is shown that all of the ammonium oxalate has not been removed.)

When the precipitate is completely washed the beaker in which the precipitation was made is placed under the funnel and a hole punched in the filter paper. The precipitate is washed into the beaker with a stream of warm water and then the filter is well washed with a hot 1.5 sulphuric acid solution. Ten c.c. of concentrated sulphuric acid is added to the washings in the beaker and the solution brought to nearly a boil, when the oxalate is titrated with a solution of potassium permanganate each cubic centimeter of which is equivalent to 0.0010 gm. CaO. The number of cubic centimeters of permanganate used, divided by 10 gives the percentage of CaO.

METHOD 2 (Washington's Method)

To 100 c.c. of Solution "A," add enough ammonia to precipitate iron and aluminum hydroxides, boil and filter through a 9-cm. filter. Wash two or three times with hot water. Remove the filter paper and contents to the original beaker, and add 2 or 3 c.c. concentrated hydrochloric acid, break up the filter paper with a glass rod and add about 50 to 75 c.c. water, and a slight excess of ammonia. Boil, and filter, catching the filtrate in the same beaker as before. Wash the iron precipitate with hot water five or six times and then discard it. The filtrates are brought to nearly a boil, 10 c.c of a saturated solution of ammonium oxalate added, the mixture allowed to cool, and 5 c.c. concentrated ammonia added.

After standing over night the mixture is filtered in a 7-cm. filter, being washed with *warm* water. The precipitate is dissolved on the filter with 1:5 nitric acid, and the solution received in the beaker in which the original oxalate precipitation was made. The filter is well washed with hot water and then dilute ammonia is poured through the filter paper to remove all traces of acid, the ammonia solution being caught in the original beaker containing the calcium. The contents of the beaker are heated to nearly boiling, made strongly alkaline with ammonia and 2 or 3 drops of ammonium oxalate solution added. After standing for at least 3 hours, the precipitated calcium oxalate is filtered through the same filter paper used above; washed with *warm* water, a hole punched in the filter and the precipitate washed through into the original beaker with 1:5 sulphuric acid. The filter is thoroughly washed, 10 c.c. of concentrated sulphuric acid is added to the contents of the beaker, and the solution brought to nearly boiling and titrated with permanganate as in Method 1.

Some of the results are shown in Table I. We have analyzed a large number of peat soils in this laboratory by both methods and have as yet found no peat soil in which the calcium could not be accurately estimated by the proposed modification. It may be, however, that such soils exist inasmuch as we have not had occasion to analyze peats containing less than 70 per cent of volatile matter.

TABLE I

COMPARATIVE CALCIUM OXIDE DETERMINATIONS BY THE PROPOSED NEW METHOD (METHOD 1) AND THE STANDARD METHOD (METHOD 2), USING PEAT SOILS

Soil No.		% Volatile	% Ash	% Insol.	% CaO Method 1		% CaO Method 2	
					I	II	I	II
A	(Analyst A)	78.68	21.32	10.26	4.63	....	4.59	4.65
B	(Analyst A)	90.59	9.41	6.12	0.63	....	0.62	0.64
B	(Analyst B)	.....	.....	.....	0.65	....	0.60	....
C	(Analyst A)	86.10	13.90	11.37	1.22	....	1.20	1.21
C	(Analyst C)	.....	.....	.....	1.24	1.24	1.25	....
C	(Analyst D)	.....	.....	.....	1.25	1.24	1.14	1.14
D	(Analyst E)	90.03	9.97	4.96	2.21	2.21	2.31	2.28
E	(Analyst E)	88.75	11.25	7.23	1.53	1.54	1.53	1.55
F	(Analyst E)	88.77	11.23	7.03	1.56	1.60	1.53	1.59
G	(Analyst E)	91.36	8.64	6.71	0.54	0.56	0.53	0.55
H	(Analyst E)	91.31	8.79	6.95	0.48	0.43	0.48	0.48
I	(Analyst E)	86.47	13.53	8.99	1.52	1.63	1.52	1.57
J	(Analyst E)	92.22	7.78	5.58	2.73	3.00	2.87	2.93
K	(Analyst E)	86.98	13.02	6.86	3.22	3.12	3.16	3.20

TABLE II

COMPARATIVE CALCIUM OXIDE DETERMINATIONS BY THE PROPOSED NEW METHOD (METHOD 1) AND THE STANDARD METHOD (METHOD 2), USING A MINERAL SOIL

	Method 1		Method 2	
	I	II	I	II
Total CaO (Carbonate fusion)	4.27	4.29	3.60	3.61
Acid soluble CaO				
12 hr. 1.115 Sp. Gr. HCl	2.68	2.71	2.59	2.39
5 days 1.115 Sp. Gr. HCl	3.27	3.28	2.84	2.84
5 Min. 5% HCl	2.66	2.72	2.51	2.51

In an attempt to apply the method to mineral soils it was found that results which were much too high were invariably obtained, even in acid extracts. Some of these results are shown in Table II. Just what factors cause the high results for mineral soils has not been determined.

SUMMARY

Calcium can be accurately determined in the acid extract of the ash of those peat soils which contain a high percentage of volatile matter by a single precipitation with ammonia and ammonium oxalate *in the presence of the iron and aluminum hydroxides* and subsequent titration of the precipitate with permanganate.

The method is not applicable to mineral soils.